TBY 2000 SAVING SOIL

FINAL REPORT

FISH AND ROYER LAKES FEASIBILITY STUDY

Submitted to:

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EXECUTIVE SUMMARY

International Science & Technology, Inc. (IS&T) has provided technical services to the Fish and Royer Lakes Association in conducting a feasibility study of the restoration of Fish and Royer Lakes under a grant from the Indiana Department of Natural Resources (IDNR) "T by 2000" Lake Enhancement Program (LEP). Both Fish and Royer Lakes are natural water bodies located in LaGrange County, approximately one mile south of the town of Plato. The larger of the two, Fish Lake has a surface area of 100 acres (40.5 ha), a maximum depth of 78 feet, and a hard bottom of marl and sand. Royer Lake has a surface area of 69 acres, a mean depth of 23.6 feet, and the bottom consists of sand and muck. The Royer Lake outlet is a navigable channel that flows into Fish Lake.

Fish and Royer Lakes have been given Indiana Department of Environmental Management (IDEM) Eutrophication Index (EI) numbers of 47 and 50, respectively, placing both lakes in the Class Two Trophic Category of intermediate quality, intermediate level eutrophic lakes. These lakes are impacted by man's activities but characterized by subtle and slowly changing trophic conditions. The watersheds of both lakes are predominantly agricultural with heavily wooded sections interspersed. The majority of the agricultural acreage is devoted to crop farming, although several animal operations (dairy and hog farming) are maintained within the watershed boundaries.

The objectives of the feasibility study were to:

- Assess the current condition of the lakes system and establish a baseline against which future changes can be measured.

- Identify potential threats to the well-being of the system, both in the lakes and in their watersheds.

- Develop mitigative strategies that have the greatest probability of success in improving the overall quality of the lakes.

In pursuit of these goals, IS&T implemented a four part program. First, all relevant background information (e.g., resource maps, soil manuals, fisheries studies) was gathered and reviewed to understand the physical setting and to assess the availability of previous research. Second, a survey was conducted on the lakes to collect data on water quality, sediment quality, phytoplankton abundance, and aquatic macrophyte distribution. Third, a watershed survey was conducted to identify upland activities resulting in excessive soil erosion and sediment/nutrient transport to the lakes. Finally, mitigative strategies were identified that would address the identified problems.

Based on the results of the watershed analysis, lake and tributary sampling, and visual observations, the primary source of sediment and nutrient loading to Fish and Royer Lakes was identified as rowcrop agriculture. No single point sources of contamination were identified however. Fish and Royer Lakes are impacted by non-point source pollution (i.e., diffuse inputs of nutrients and sediments). As such, increased eutrophication of the lakes cannot be tied to specific causal agents or sources within the watershed. In general, the areas within the watershed displaying the highest erosion rates were those that combine intensive-till farming, hilly slopes, and erodible soil types. Sampling and modeling analyses indicate that the transport of sediments and nutrients to the lakes is primarily through stream channels.

In addition to runoff, sources of nutrient loading to the lakes include internal sediment nutrient release, septic systems located around the perimeter of the lakes, and atmospheric deposition. Septic systems are probably contributing significant amounts of nutrients as a result of aging systems installed in poorly suited soils. The estimated phosphorus loading to Royer Lake from septic systems was approximately 45 percent greater than that in Fish Lake (135 lbs/year vs. 93 lbs/year, respectively). Relatively high nitrogen to phosphorus (N:P) ratios (i.e., greater than 90) observed in the lake water samples suggest that significant sources of nitrogen loading exist in the system, and that phosphorus is the nutrient limiting productivity in the lakes. Both of the lakes are experiencing symptoms of eutrophication, although Fish Lake appears to be relatively healthy. Trophic conditions in Royer Lake may be expected to deteriorate under the current loading conditions.

The primary thrust of management efforts should be directed at controlling sediment and nutrient production in the watershed. Limiting the input of these parameters offers the most promising avenue for maintaining the quality of the resource. A general, integrated program for managing Fish and Royer Lakes should include: (1) application of appropriate best management practices (BMPs) in the watershed, especially near stream corridors and at animal waste facilities; (2) effective waste water treatment and septic system maintenance at lake shore residences; and (3) identification, preservation, and restoration of significant wetlands in the watershed that can contribute to maintaining water quality. Because of the fact that soils immediately adjacent to the lakes are generally poorly suited for septic drain fields, alternative waste treatment systems should be considered when replacing failed systems or planning new construction. The Fish and Royer Association, and other residents in the watershed, should become familiar with agricultural BMPs for controlling sediment and nutrient export to surface waters. The Association should work with the SCS District Conservationists's office and IDNR to encourage the implementation of BMPs, especially in the critical areas identified in this report.

SECTION 1. INTRODUCTION

International Science & Technology, Inc. (IS&T) has provided technical services to the Fish & Royer Lake Association (FRLA) in conducting a feasibility study on the restoration of Fish and Royer Lakes. The work was performed under provisions of the "T by 2000" Lake Enhancement Program (LEP) administered by the State Division of Soil Conservation, Indiana Department of Natural Resources. The LEP was established to ensure the continued viability of Indiana's public-access lakes by (1) controlling sediment and nutrient inflows, and (2) implementing remedial actions to forestall or reverse the impacts of such inflows. Feasibility studies funded through the LEP are intended to document the potential need and scope of future lake enhancement actions.

1.1 FISH AND ROYER LAKES

Fish and Royer Lakes are located in LaGrange County, Indiana, approximately one mile south of the town of Plato (Figure 1-1). Fish Lake is a 100 acre (40.5 ha) natural lake with a maximum depth of 78 feet (23.8 m), a mean depth of 40.5 feet (12.3 m) and a hard bottom of marl and sand (IDNR, 1978). The lake is characterized by a steep bottom gradient and a limited littoral zone. There are two unnamed tributaries to Fish Lake. One tributary enters from the northeast, draining Grass Lake and surrounding wetlands. The second tributary is the channel that enters Fish Lake from the south, connecting it to Royer Lake. Royer Lake is a 69 acre (27.9 ha) natural lake comprised of two sub-basins having maximum depths of 59 and 56 feet (17.9 and 17.1 m). The mean depth of this lake is 23.6 feet (7.2 m) and the bottom consists of sand and muck (IDNR, 1978). This lake is also characterized by a steep bottom gradient and limited littoral zone. There are two tributaries into Royer Lake, one from the south and one from the east. The Royer Lake outlet is a navigable channel that flows into Fish Lake.

Fish and Royer Lakes were assigned Indiana Department of Environmental Management (IDEM) Eutrophication Index (EI) numbers of 39 and 26, respectively (IDEM, 1986). IS&T contacted H. BonHomme to confirm these numbers. Mr. BonHomme reviewed and revised the EI values to 42 and 45, respectively. The changes resulted from errors that were discovered in the original calculations published in 1986. These revised values place both lakes in the Class Two Trophic Category of intermediate quality, intermediate level eutrophic lakes. These lakes are impacted by man's activities and are characterized by subtle and slowly changing trophic conditions.

Fish Lake falls within the Lake Management Group II-C, based on its original IDEM trophic classification. Group II-C lakes have deeper mean depths (32.7 - 40.5 ft.) and EI numbers between 18 and 41. Although the revised EI value (i.e., 42) is technically above the II-C range defined by IDEM, this group still provides the best fit for the lake. It should be noted that the lake groups were defined based on a cluster analysis, and therefore category assignments should be considered somewhat flexible. Management strategies for restoring Group II-C lakes usually focus on curbing nutrient inputs through land use practices (buffer corridors), and in-lake restoration by means of selective discharge, nutrient inactivation, or macrophyte harvesting.

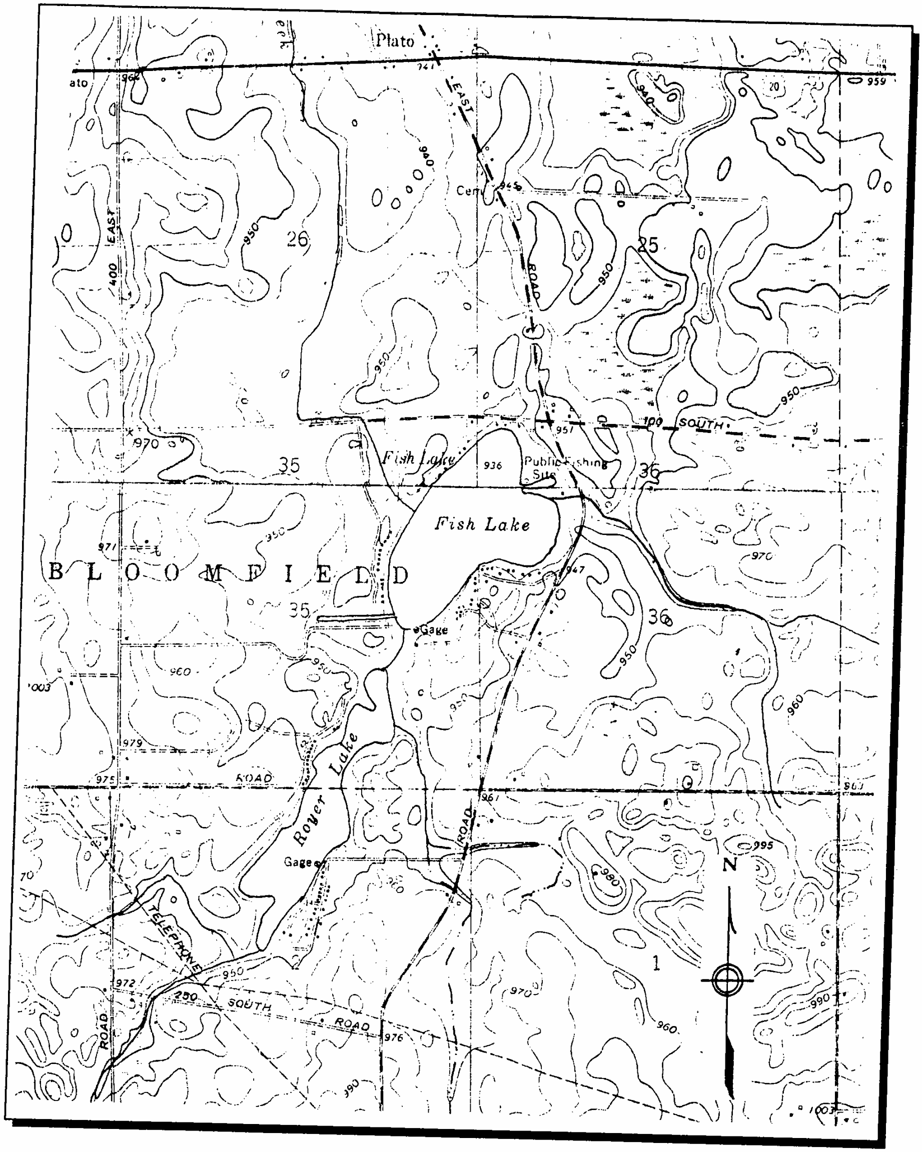


FIGURE 1-1. **Portion of U.S. Geological Survey (USGS) Mongo and Wolcottville quadrangles showing the locations of Fish and Royer Lakes.**

Royer Lake was assigned to the Lake Management Group IV-A based on its originally published EI number. The revised EI number places Royer Lake in the IV-D Lake Management Group. Lakes in this management group are characterized by intermediate mean depths (21 - 31 ft.) and EI numbers between 46 and 67. Lake Management Group IV contains the majority of problem lakes in the state. The management priority for these lakes is water quality improvement through restoration and nutrient abatement. In-lake restoration techniques applicable to these lakes include bottom sealing, dredging, or sediment consolidation. Suggested land use and watershed practices to curb nutrient and sediment inputs include implementation of erosion control techniques, wetland protection, and establishment of shoreland corridors for agricultural areas adjacent to the lake and tributary streams.

The watersheds of both lakes are predominantly agricultural with heavily wooded sections interspersed. The majority of the agricultural acreage is devoted to crop farming, although several animal operations (dairy and hog farming) are maintained within the watershed boundaries. The northeast tributary to Fish Lake drains 4,075 acres (1649 ha) of predominantly agricultural cropland. Very few animal operations exist within this watershed. The Royer Lake watershed is primarily agricultural land draining 3,650 acres (1477 ha). The eastern tributary to Royer Lake flows through several animal farming operations located approximately one mile upstream of the lake. The south tributary to Royer Lake flows through a wetland area on the southern shore prior to entering the lake. Several animal farming operations, as well as farm fields, are located in proximity to this stream. Conservation tillage practices are currently in use in portions of the Fish and Royer Lakes watershed, with mulch-till and no-till being the primary practices. Many fields, however, are still planted to the edges of the tributary streams, providing little area to act as a buffer to sediment and nutrient input.

In the document entitled *Survey of 24 LaGrange County Lakes* (Grant, 1989) interpretations were made of aerial photographs dated 1938, 1965, and 1986. An additional aerial photograph from 1951 was interpreted by IS&T.

During the 1930's, the shoreline of Fish and Royer Lakes was completely undeveloped with the exception of one small building on the southeast shore and two farmhouses on the north shore of Fish Lake. An aerial photograph, dated September 1938, showed the undeveloped shoreline of Fish Lake to consist of a narrow band of wetlands extending from 100 to 400 feet (31 and 122 m) inland from the lake along the eastern and southern shores, dense woodland areas along a portion of the western shore, and the remaining shore being farmland extending to the lake edge. Small wetlands covered approximately half of the Royer Lake shoreline in the 1938 aerial photograph. The remaining shoreline consisted of narrow strips of brush separating the lake from farm fields that extended almost to the lake edge.

Aerial photography from 1951 indicated a slight increase in residential development along the southeast shore of Fish Lake, with the remaining shoreline unchanged. The Royer Lake shoreline, in 1951, also had remained undeveloped and was characterized by small wetlands along a portion of the shore. The narrow strips of brush that had separated the lake from farm fields in 1938 had become a zone of wooded acreage and natural vegetation by 1951.

Between 1951 and 1965, residential development grew to encompass nearly the entire shoreline of Fish Lake, as well as the western shore and a portion of the eastern shore of Royer Lake. Aerial photography from 1965 showed only small areas along the eastern and western shores of Fish Lake have remained undeveloped. The wetlands surrounding the lake either had been filled or drained and two channels had been constructed, one on the southwestern shore and one on the northeastern shore. The channel constructed on the southwestern shore of Fish Lake is in a wooded area occupied by a trailer court. The channel on the northeastern shore is in the public access site. This channel was dug to obtain fill for the access site, which now occupies what was once the largest wetland on Fish Lake. A circular channel had been dug along the southeastern shore of Royer Lake by 1965, as seen in the aerial photograph from that year. The circular channel created an island and provided additional lake access for residential development. The wetland area along the northeastern shore had been partially filled and two residences built. Wetland areas along the eastern and southwestern shores of Royer Lake had begun to support small stands of trees.

By 1986, aerial photography showed Fish Lake to be heavily developed with the exception of a portion of the eastern shore. Additionally, the channel between Fish and Royer Lakes had been completely developed. The eastern tributary to Fish Lake had been diverted so that it entered Fish Lake at a point slightly south of the original inlet. Royer Lake had not experienced as great an amount of development as Fish Lake. A 1985 Indiana Department of Natural Resources (IDNR) Fisheries Survey noted residential development along approximately 85 percent of the Fish Lake shoreline and 35 percent of the Royer Lake shoreline. Aerial photographs from 1986 showed undeveloped areas along the northeast, southwest and south shoreline of Royer Lake. The western and southeastern shores of the lake support the greatest density of residential development.

1.2 NATURE OF THE PROBLEM

Nutrient and sediment loading to Fish and Royer Lakes has resulted in a decline in water quality and general lake condition. The primary source of these inputs has been identified as agricultural runoff (Grant, 1989). Other sources of nutrients may include leachate from septic systems along the shoreline and/or nutrient release from the lake sediments during periods of anoxia. Both lakes experienced algal blooms during the summer of 1989. Additionally, aerial reconnaissance during the summer of 1989 showed heavy sediment input from the Royer Lake drainage basin after a precipitation event.

1.3 STUDY OBJECTIVES

The objectives of this feasibility study were to assess the current trophic status of Fish and Royer Lakes, identify the sources of potential threats to the lakes, and recommend appropriate mitigative strategies. This effort included a compilation of historical data pertaining to the lake systems and their watersheds (Section 2.1); a field survey of existing watershed activities and lake condition (Sections 2.2 and 2.3); an analysis and evaluation of all lake and watershed information, including a watershed modeling study (Section 3); identification of all appropriate mitigative strategies (Section 4); and a presentation of conclusions and recommendations (Section 5).

SECTION 2. METHODS

This section of the report provides descriptions on the methods used in conducting the Fish and Royer Lake Feasibility Study. Data collection involved three sub-tasks: (1) a literature survey; (2) a lake survey; and (3) a watershed survey. These sub-tasks are described below.

2.1 LITERATURE SURVEY

A survey of existing information was performed to identify and obtain all historical water quality, hydrologic, and land use data relevant to Fish and Royer Lakes. Contacted agencies included:

- LaGrange County Health Department
- LaGrange County Surveyor's Office
- Indiana Department of Environmental Management (IDEM)
- Indiana Department of Natural Resources (IDNR)
- U.S. Soil Conservation Service (LaGrange County)

Water quality data were requested from the LaGrange County Health Department, and the IDEM. Although all types of water quality information were sought, parameters of specific interest included nutrients, Secchi disk transparency, chlorophyll-a, total solids, fecal coliform, and dissolved oxygen. Biological data (e.g., species composition, abundance) were also sought.

Climatic, hydrologic, and physiographic information was obtained through the LaGrange County Surveyor's Office, the U.S. Soil Conservation Service (SCS), the U.S. Agricultural Stabilization and Conservation Service (ASCS), the U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA). Data sources included:

- Aerial photographs
- Topographic maps
- Soil surveys
- Erodible soil maps
- Agricultural practice reports
- Lake bathymetric maps
- Wetland reports
- Precipitation chemistry reports

Because USGS land use maps were not available for LaGrange County, aerial photographs, topographic maps, and ground surveys were combined to delineate land use coverage in the watershed (Section 2.3.4).

2.2 LAKE SURVEY

In order to obtain information required for a detailed assessment of the current conditions in Fish and Royer Lakes, a field survey was conducted during the late summer and fall of 1989. Components of the survey, and the dates on which they were conducted are as follows:

- In-situ water quality measurements (August 24, 1989)
- Chemical water quality measurements (August 24, 1989)
- Biological water quality measurements (August 24, 1989)
- Aquatic macrophyte mapping (September 28 - 29, 1989)
- Bathymetric mapping (September 28 - 29, 1989)

The locations of sampling sites are presented in Figure 2-1.

2.2.1 In-situ Measurements

In-situ water quality parameters were sampled in the deepest area in each lake at stations FL_{WQ} and RL_{WQ}. Measurements of pH, dissolved oxygen (DO), temperature, and conductivity were made using a Hydrolab Surveyor II (Hydrolab Corporation, Austin, TX). In Fish Lake, these measurements were recorded at 5 foot (1.5 m) intervals from the water surface through the thermocline, and at 10 foot (3 m) intervals thereafter to just above the surface of the sediment. Measurements in Royer Lake were recorded at 5 foot (1.5 m) intervals from the surface to immediately above the sediment surface. Light transmission at a depth of 3 feet (0.9 m) was recorded using a Martek Model XMS (Martek Corporation, Irvine, CA) transmissometer. The transmissometer was calibrated in sunlight (i.e., 100 percent transmission) just above the lake surface at each sampling site. Secchi disk transparency was also measured. The data were used to characterize summer conditions in the lake and to construct an index of trophic status.

2.2.2 Chemical Measurements

Water samples were collected with a 6.6 quart (6.2 l) Van Dorn sampler (Wildco Supply Company, Saginaw, MI) at stations FL_{WQ} and RL_{WQ}. Samples were taken at three depths in each lake: (1) just below the lake surface; (2) near the thermocline, at mid-depth; and (3) one foot (.3 m) above the lake bottom. The mid-depth stations were at 40 ft. (12.2 m) in Fish Lake and 25 ft. (7.6 m) in Royer Lake. The bottom sample in Royer Lake was collected at a depth of 50 ft. (15.2 m). In Fish Lake, the bottom sample was collected at a depth of 55 ft. (16.8 m) rather than at 75 ft (22.9 m) due to a lack of line on the sampler.

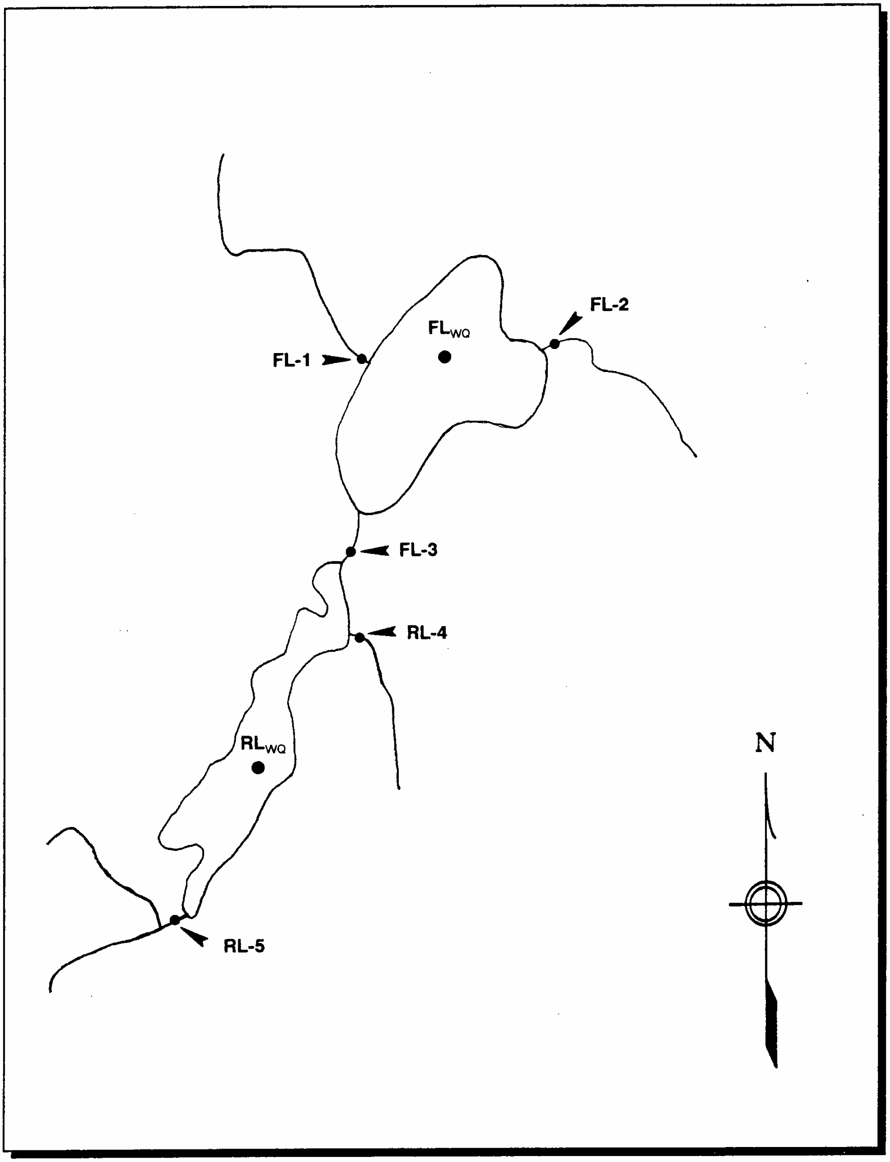


FIGURE 2-1. Locations of inlake and storm sampling stations on Fish and Royer Lakes.

Samples were marked and placed in acid-washed, one-liter Cubitainer containers (Hedwin Corporation, Baltimore, MD). Separate fecal coliform aliquots from each depth were placed in six-ounce Whirl-Pak bags (Nasco, Inc., Fort Atkinson, WI). All samples were stored on ice in the dark and subsequently shipped to the IS&T analytical laboratory via overnight air freight. The samples were received and the analyses were begun within 24 hours of collection. Parameters and methods used in the chemical determinations are listed in Table 2-1. Results were used to characterize summer conditions in the lakes and to construct trophic status indices.

TABLE 2-1. Chemical parameters and analytical methods used in evaluating water samples from Fish and Royer Lakes.

PARAMETER	METHOD	REFERENCE
Chlorophyll a (Chl-A)	Spectrophotometer	APHA, 1985
Fecal Coliform	Incubation, visual count	APHA, 1985
Ammonia (NH_4-N)	Flow Injection Analysis	EPA, 1983
Nitrate (NO_3)	Flow Injection Analysis	EPA, 1983
Total Kjeldahl Nitrogen (TKN)	Flow Injection Analyses	EPA, 1983
Ortho-Phosphorus (OP)	Flow Injection Analysis	EPA, 1983
Total Phosphorus (TP)	Flow Injection Analysis	EPA, 1983
Total Suspended Solids (TSS)	Gravimetric	EPA, 1983

Water quality samples were collected from the four tributaries and the one outlet of Fish and Royer Lakes (Figure 2-1) following a storm event on September 14, 1989. These grab samples were collected by a volunteer from the Fish and Royer Lake Association at stations FL-1, FL-2, FL-3, RL-4, and RL-5. The samples were placed in clean, rinsed, and labeled 1-liter Cubitainer containers and immediately stored in a refrigerator. IS&T personnel collected the samples from the lake volunteer, placed them on ice, and shipped them to the IS&T analytical laboratory. The samples were received at the laboratory within 48 hours of collection.

2.2.3 Biological Measurements

Phytoplankton samples were collected at the two in-lake stations FL_{WQ} and RL_{WQ} using a 0.5 meter diameter, 80.0 μ mesh net. Vertical tows were made from depths of 5 feet (1.5 m) and 20 feet (6.1 m). The latter depth was chosen so that the sample would include water from just below the thermocline. Samples were preserved with Lugols solution (APHA, 1985), stored in 1-liter containers, and shipped with the water quality samples. To calculate total sample volume, the area covered by the mouth of the net was multiplied by the length of the tow (i.e., π X 0.25^2 m X 1.5 m) and then converted to liters. The total cell count was divided by the sample volume to obtain the number of plankton cells per liter. Phytoplankton identifications were made using the settling chamber-inverted microscope technique described by H. Utermohl (Sournia, 1972). The results were used in the calculation of a lake trophic index.

2.2.4 Bathymetric Mapping

Bathymetric surveys of Fish and Royer Lakes were conducted using an Eagle Mach 1 recording fathometer (Eagle Electronics, Catoosa, OK) operated from a 15-foot Jon boat. Survey transects ran perpendicular to the lake shorelines and were located by referencing them to unique shoreline features (Figure 2-2). This approach provided for accurate placement of survey transects on USGS topographic maps. Each transect was traversed at a constant boat speed and fathometer recordings were annotated at the beginning and end of each run. Fathometer traces were subsequently digitized. Bathymetric maps were produced using "Surfer," (Golden Software, Inc., Golden, CO) a contour mapping software package. Maximum depth, mean depth, and lake volume were calculated from area/volume ratio analyses of the bathymetric maps.

2.2.5 Aquatic Vegetation Mapping

Hydrophytic vegetation was surveyed to quantify and map the distribution of floating, emergent, and submergent plant species. The perimeter of each lake was canvassed on foot and by boat. Plant specimens were collected, photographed, and identified to the species level in the field. *A Manual of Aquatic Plants* (Fassett, 1980) was used for identification. Areal coverages were sketched and digitized to create plant distribution maps.

2.2.6 Trophic State Assessment

A BonHomme Eutrophication Index (EI) was calculated for both Fish and Royer Lakes. The index combines information about several diverse parameters into a single number intended to describe the degree of lake aging brought on by external inputs. Points are assigned for lake trophic parameters to give scores from 0 to 75, with values near 0 being the least eutrophic. EI values can be used as a basis for establishing and comparing priorities for lake remediation throughout the state. It should be noted,

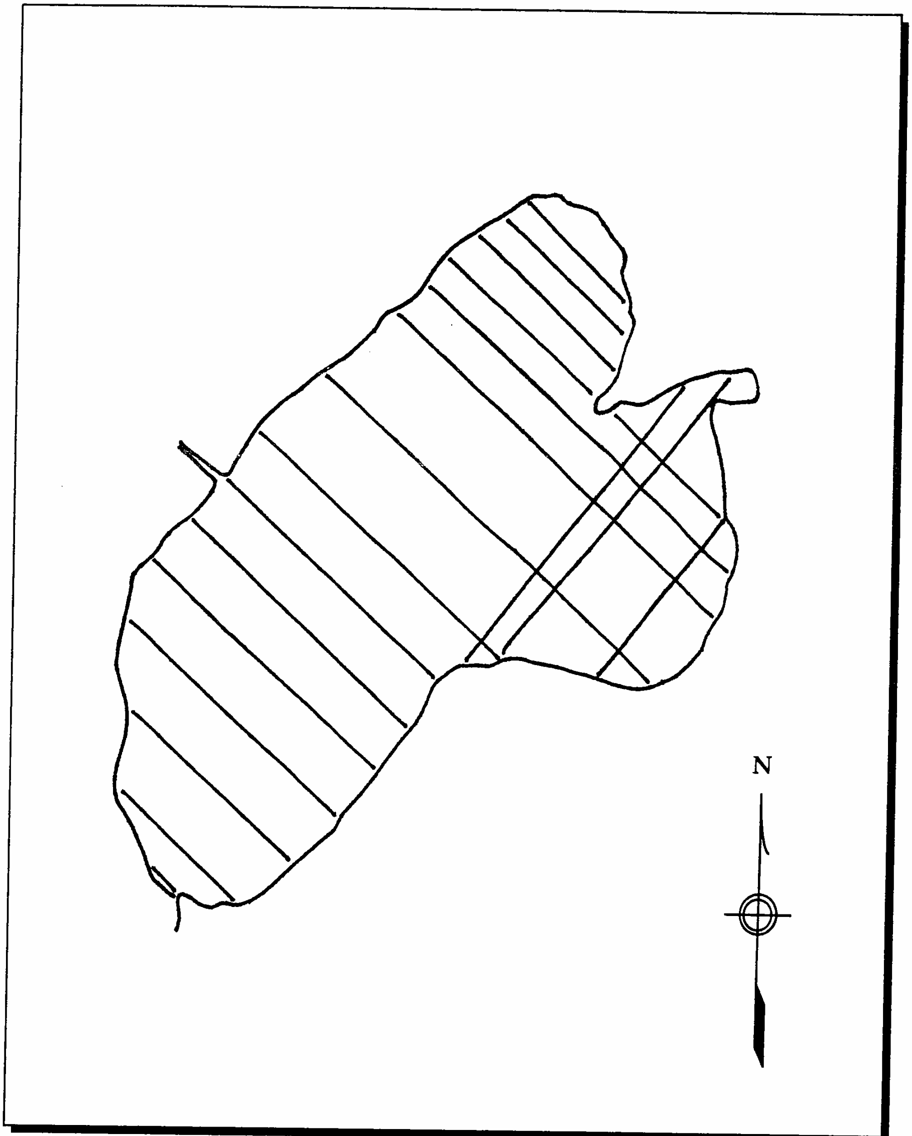


FIGURE 2-2. Survey transects used in Fish Lake.

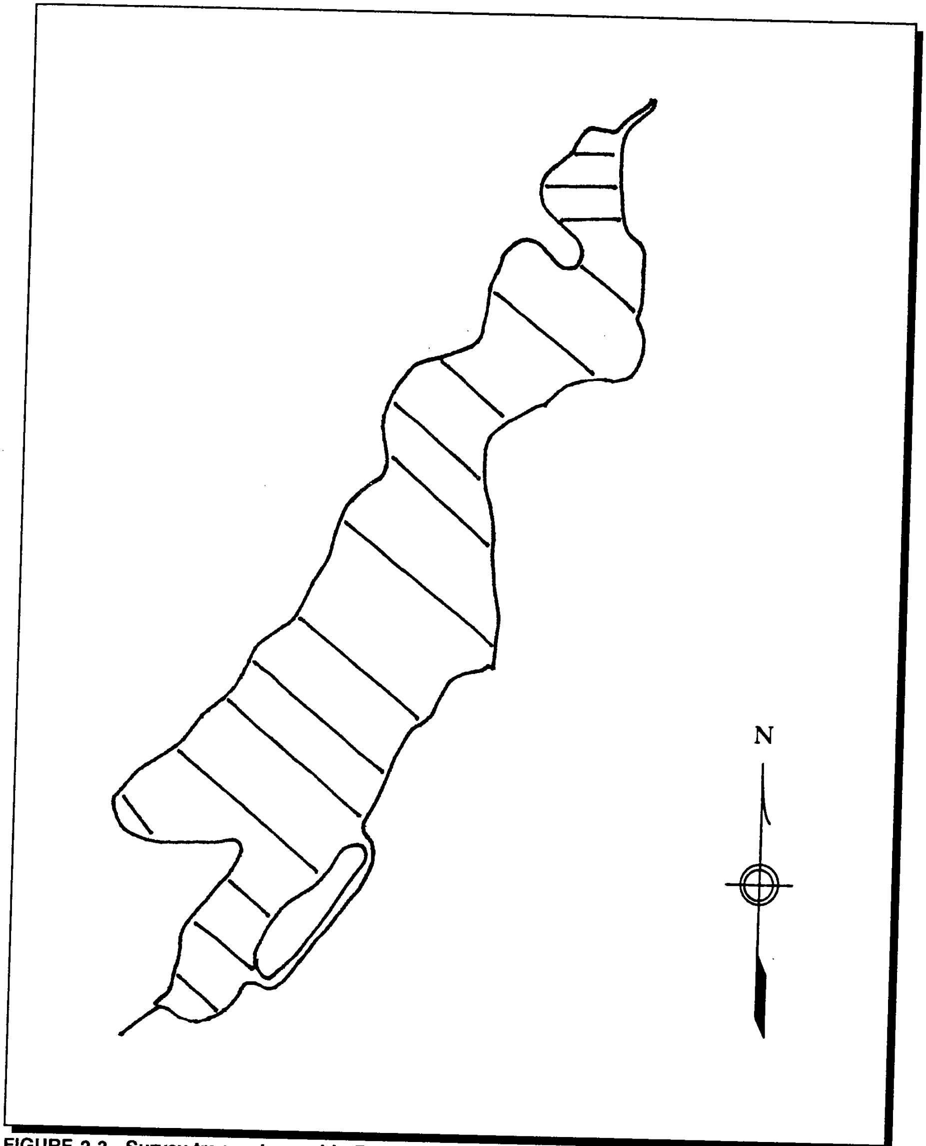


FIGURE 2-3. Survey transects used in Royer Lake.

however, that the data used to construct the EI are typically derived from a single sampling event and, therefore, only capture conditions as they exist on a single day in summer.

Another numerical index that was used for trophic state assessment is the Carlson Trophic State Index (TSI). Carlson (1977) based his index on algal biomass using the log transformation of Secchi disk transparency, Chl a, and TP concentrations. All three measurements are taken from surface waters where phytoplankton productivity is at its peak. The equations used for computing the Carlson TSI are shown below:

$$TSI(SD) = 10\left(6 - \frac{\ln SD}{\ln 2}\right)$$

Where:
TSI (SD) = TSI based on Secchi disk transparency
SD = Secchi transparency (m)

$$TSI(Chla) = 10\left(6 - \frac{2.04 - 0.68 X \ln Chla}{\ln 2}\right)$$

Where:
TSI (Chl a) = TSI based on chlorophyll concentration
Chl a = Chlorophyll a (ug/L^3)

$$TSI(TP) = 10\left(6 - \frac{\ln \frac{48}{TP}}{\ln 2}\right)$$

Where:
TSI (TP) = TSI based on total phosphorus concentration
TP = Total phosphorus (ug/L^3)

The Carlson TSI classifies lakes on a scale of 0 to 100, with each major scale division (i.e., 10, 20, 30,...) representing a doubling in algal biomass. Under ideal circumstances, the three separate TSI values should be similar. Under realistic conditions, however, the index values will exhibit some variability.

It is this variability that reveals the basic differences in the ecological functioning of the aquatic system. The accuracy of Carlson's TSI (SD) is diminished by the presence of non-algal particulate matter or highly colored water. The index derived from the Chl a values, when available, is best for estimating algal biomass, and priority should be given for its use as a trophic state indicator (Carlson, 1977).

2.3 WATERSHED SURVEY

A comprehensive effort was undertaken to describe conditions in the watersheds of both lakes. Special attention was directed to existing activities that could result in excessive sediment or nutrient loading (e.g., land clearing, construction, intensive tilling). Components of the watershed survey included:

- Climatic evaluation
- Hydrologic characterization
- Soil type delineation
- Land use delineation
- Sediment/nutrient modeling

2.3.1 Climatic Evaluation

Two types of atmospheric information were obtained and analyzed during the study: (1) general climatic data (e.g., temperature, rainfall, solar radiation); and (2) precipitation chemistry data. General climatic conditions in the Fish and Royer Lakes watershed were described from reports compiled by the U.S. Department of Commerce (DOC, 1968) and by the Soil Conservation Service (USDA, 1977). In addition, a weather simulation program (Nick and Lane, 1989) was used to construct 30-year, monthly averages for maximum temperature, minimum temperature, total precipitation, storm duration, and solar radiation. Historical atmospheric information for the Fort Wayne area was obtained from the National Climatic Data Center and used to represent conditions in LaGrange County. Detailed descriptions of the parameters, statistics, and routines incorporated in the weather model are presented in the above-noted reference.

Specific information on precipitation chemistry was unavailable for Fish and Royer Lakes, therefore, interpolated averages from data collected at the closest Great Lakes monitoring stations (i.e., Benton Harbor, Michigan and Put-in Bay, Ohio) were used to estimate total phosphorus and total nitrogen inputs from annual rainfall. No data were available to estimate dry loading.

2.3.2 Hydrologic Characterization

Hydrological characterization of the watershed centered around two types of analyses: (1) a general description of watershed and lake morphological attributes, including evaluation of physical indices relating watershed size and shape to runoff behavior; and (2) calculation of an approximate mass-balance water budget. The watershed boundary was outlined on 7.5 Minute Series USGS topographic maps. A computerized opisometer (i.e., map distance/area measuring device) was used in conjunction with mechanical means to determine the nature of watershed features including total area and perimeter, axial length, average width, average slope, maximum and minimum slope, center of gravity, drainage pattern, drainage density, shape factor, compactness coefficient, eccentricity, and orientation. Lake surface area and perimeter were also measured. A description of the significance of each of these factors is presented below.

Area:	The extent of the ground surface inside the catchment; area is a fundamental unit of interest in all watershed studies.
Perimeter:	The length of the boundary around the catchment; perimeter is helpful in determining watershed shape characteristics.
Axial Length:	The distance between the watershed outlet (i.e., lake overflow) and the farthest point on the catchment boundary; axial length is helpful in determining the time required for rain water falling on the most remote section of the catchment to reach the overflow (i.e., maximum time necessary for trans-watershed flow).
Average Width:	Literally, the ratio of catchment area to axial length; average width is a shape descriptor.
Average slope:	A measure of elevation change per unit of horizontal distance within the catchment; average slope describes the general "steepness" of the watershed. "Steepness" partly determines the velocity (i.e., erosional capacity) of runoff.
Minimum slope:	Another measure of elevation change per unit of horizontal distance within the catchment; minimum slope describes the lowest degree of "steepness" in the watershed. This parameter is often used with its counterpart, maximum slope, to indicate the range of "steepness."
Maximum slope:	A third measure of elevation change per unit of horizontal distance within the catchment; maximum slope describes the highest degree of "steepness" in the watershed. This parameter is often used with its counterpart, minimum slope, to indicate the range of "steepness."

Center of Gravity:	The areal centroid of the catchment; this measure pinpoints the exact center of the watershed.
Drainage Pattern:	The arrangement of natural channels within a catchment; drainage pattern not only describes the layout of the streams but also indicates the types of existing soils/bedrock (i.e., drainage configurations are dependent on the erosional resistance of the existing substrate).
Drainage Density:	The ratio of catchment stream length to catchment area; drainage density measures the efficiency of drainage afforded by defined channels (i.e., extensive stream networks lead to efficient drainage).
Form Factor:	The ratio of watershed average width to axial length; the form factor indicates the relative shape of the watershed.
Compactness Coefficient:	The ratio of the perimeter of the watershed to the perimeter of a circle with an equal area; the compactness coefficient indicates the nature and timing of runoff contributions to stream flow (i.e., circular watersheds are regular in shape and tend to have all areas contributing runoff equally within a distinct time span; non-circular watersheds tend to have nonuniform and less predictable runoff characteristics).
Eccentricity:	A measure relating watershed shape to an ellipse; this parameter also indicates the nature and timing of runoff contribution to stream flows.
Orientation:	Synonymous with "aspect"; orientation indicates the compass direction toward which most slopes in the watershed face.

An annual water budget was developed for Fish & Royer Lakes based on estimates of water mass inputs and outputs (Table 2-2). Parameters considered as inputs included direct rainfall, runoff, and spring inflow. Parameters considered as outputs included lake outlet overflow, evaporation, and basin leakage. Annual rainfall volumes applied to the water budget were derived from 30-year averages produced by the computerized weather generator (Section 2.3.1). Runoff volumes were calculated using the Curve Number Method described in U.S. Soil Conservation Service Technical Release 55 (USDA, 1986). Lake evaporation was interpolated from pan evaporation figures supplied in the Weather Atlas of the United States (DOC, 1968). Because data for springs and leakage in the lake were unavailable, these factors were assumed to be negligible. Lake overflow was calculated as the residual of inflow minus evaporation. No other water inflows or outflows were identified.

TABLE 2-2. **Mass-balance relationship and input/output parameters considered in the water budgets for Fish and Royer Lakes.**

MASS-BALANCE RELATIONSHIP:	Inputs = Outputs
INPUTS:	OUTPUTS:
Rainfall (monthly/annual) Stream flow/Runoff (monthly/annual) Under-basin Springs[1]	Lake Overflow (monthly/annual) Evaporation (monthly/annual) Under-basin Leakage[1]

[1] Assumed to be 0 because no data were available for these parameters.

In addition to water budget parameters, estimates were made for potential evapotranspiration and hydraulic retention time. Potential evapotranspiration (PET) is a measure of maximum possible evaporation through the soil and vascular plants, given an unlimited water supply. Estimates of PET were generated using the Thornthwaite Method (Thornthwaite and Mather, 1956), an empirical technique based on mean monthly temperatures. This technique was chosen over other methods because the information requirements were readily met by the existing climatic data.

Hydraulic retention time is a measure of the time required for the volume of lake inflow water to equal the volume of the lake itself. It can be thought of as the period of time necessary to completely replace the volume of a lake. For this study, hydraulic retention time was computed as the ratio of lake water volume to the annual inflow water volume. Results were expressed in terms of years.

2.3.3 Soils

The types and extent of soils in the Fish & Royer Lakes watershed were identified using the LaGrange County Soil Survey (SCS, 1980). The information gathered was incorporated into sediment/ nutrient models (Section 2.3.5).

2.3.4 Land Use Delineation

Land use coverages in the Fish and Royer Lakes watershed were identified and delineated using a combination of (1) USGS 7.5 minute series topographic maps; (2) aerial photographs (1 to 2,000 scale); and (3) site reconnaissance. The watershed boundary was outlined on topographic maps and digitized along with key geographical features (e.g., lake shorelines, streams, roads, towns). Using aerial photographs, land uses were delineated and assigned to one of sixteen possible categories (Table 2-3). The land uses were then digitized and overlain onto the watershed boundary and geographical feature files. Coverage maps and tabular summaries of land use in the entire watershed and in sub-basins were

TABLE 2-3. **Land use categories designated in the watershed survey.**

1)	Water Surface
2)	Wetlands (including approx. stream corridors)
3)	Forest (tree groups larger than 1/4 acre)
4)	Open Land/Vacant Lots (no structures or livestock)
5)	Pasture (grazed lands)
6)	Row Crops (corn, beans, etc.)
7)	Non-row Crops (grains)
8)	Orchard
9)	Feedlot
10)	Low Density Residential (1 dwellings/acre)
11)	Medium Density Residential (2-4 dwellings/acre)
12)	High Density Residential (5 or more dwellings/acre)
13)	Commercial/Industrial (industrial parks, malls)
14)	Parks
15)	Bare Ground (construction sites)
16)	Resource Extraction (borrow pits, timber sites)

produced for this report with IS&T proprietary software. Results were used as input parameters for modeling sediment/nutrient dynamics (Section 2.3.5).

2.3.5 Sediment/Nutrient Modeling

Information on land use, climate, soils, and hydrology were combined to provide input parameters for use in the Agricultural Nonpoint Source Pollution Model (AGNPS), a system developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service. The microcomputer-based model was designed to evaluate the sediment, nutrient, and hydrologic quality of runoff from land in agricultural regions. AGNPS operates on a grid basis and requires the watershed to be divided into a series of uniform square areas called "cells." Twenty-two physical and chemical characteristics must be defined and input for each cell before the model is run (Table 2-4). Potential pollutants are routed through the watershed starting at cells along the basin divide and moving toward the outlet in a stepwise manner. Depending on the defined parameters, each cell exerts an influence on the runoff, either increasing or diminishing the nonpoint pollutant load. Sediment, nutrient, and hydrologic characteristics may be summarized for any cell along the flow path and at the watershed outlet. The model provides estimates for single precipitation events only, and, therefore, requires the user to define a "design storm" for the analysis.

Based on the recommendations of AGNPS developers, the Fish and Royer Lakes watershed was divided into a series of 10-acre cells. Each cell was then summarized according to the parameters listed in Table 2-4. The design storm chosen for this exercise was the 2-year, 24-hour event (i.e., the largest storm

TABLE 2-4. **Input parameters used in the AGNPS model[1].**

PARAMETER	DESCRIPTION
Cell Number	ID number of current cell
Receiving Cell	ID number of cell receiving outflow from current cell
SCS Curve Number	Relates runoff mass to rainfall mass (inches)
Field Slope	Mean slope of fields (%)
Slope Shape	Shape of slopes (i.e., concave, convex, or uniform)
Slope Length	Mean slope length of fields (feet)
Channel Slope	Mean slope of stream channel (%)
Side Slope	Mean slope of stream channel banks (%)
Roughness	Manning's "roughness" coefficient for channels
Soil Erodibility	K-Factor from Universal Soil Loss Equation
Crop Practice	C-Factor from Universal Soil Loss Equation
Conservation Practice	P-Factor from Universal Soil Loss Equation
Surface Condition	Indicates degree of land surface disruption
Aspect	Principal drainage direction
Soil Texture	Gross texture of the soil (i.e., sand, silt, clay, or peat)
Fertilization	Level of added fertilizer
Incorporation	Percentage of fertilizer left on soil after the storm
Point Source Flag	Indicates presence/magnitude of point source (e.g., treatment plant)
Gully Source	Estimate of the magnitude of gully erosion
COD	Level of chemical oxygen demand generated
Impoundment Flag	Indicates presence/number of terrace systems
Channel Flag	Indicates presence/number of defined streams

1 Parameters represent estimated conditions within each cell.

lasting 24 hours that can be expected to occur once every 2 years). This storm was chosen because: (1) suitable climatic input data were available; (2) the storm was large enough to produce meaningful model output; and (3) the storm was small enough to be considered fairly common. Nutrient, sediment, and runoff maps highlighting potential watershed "trouble spots" were subsequently produced using the AGNPS output data and a graphics program.

2.3.6 Septic System Inputs

All available septic system data were obtained from the LaGrange County Health Department, the U.S. Census Bureau, and other appropriate county, state, and Federal agencies. This information included figures for age, loading level, and loading capacity of systems potentially impacting the lakes. Data on population (i.e., total population and individuals per dwelling), soil conditions (i.e., slope, drainage characteristics), and expected system life spans (i.e., half-life figures for systems in various Indiana soils) were collected. Overall load estimates, age values, and life span data were combined for systems near the lakes to provide an assessment of overall septic load to each water body.

SECTION 3. SURVEY RESULTS AND DISCUSSION

Results of the literature, lake, and watershed surveys are presented in this section of the report. Most of the discussion centers on the findings of the lake and watershed surveys, with references to the literature search assuming a supporting role. Pertinent data collected during the literature survey has been included in a separate section to provide a historical perspective of the conditions in the lakes. Identification of sediment and nutrient sources within the watershed is provided following presentation of the survey results and serves to summarize the study findings in practical, management-oriented terms.

3.1 LITERATURE SURVEY

Table 3-1 presents a summary of the historical data obtained for Fish and Royer Lakes from the Indiana Department of Natural Resources (IDNR), Indiana Department of Environmental Management (IDEM), Indiana State Board of Health (ISBH), and the LaGrange County Health Department (LCHD). Sources of historical data identified during this study include information on water quality, fish population surveys, aquatic plants, soil types, and land use. Information on significant natural areas and the occurrence of rare, threatened, or endangered species located in the drainage basin was obtained from the Division of Nature Preserves, IDNR.

3.1.1 Water Quality

Fish and Royer Lakes were two of 24 lakes sampled during the summer of 1988 by the LaGrange County Health Department. Parameters of interest included nutrient analyses as well as algal species composition. The results of nutrient analyses are consistent with earlier data for these lakes, and are generally indicative of eutrophic conditions. Algal species identified included *Oscillatoria*, the most common genera observed, as well as *Chlorococcum*, *Volvox*, *Chlamydomonas*, and *Eudorina*.

A summary of water quality data collected on the tributaries of Fish and Royer Lakes by the LaGrange County Health Department during the summer of 1988 is presented in Table 3-2. The data include nutrient analyses of these tributaries. The substantially higher TP concentrations in the tributaries to Royer Lake than those to Fish Lake would support the suggestion that the majority of nutrient loading to Fish Lake is occurring through the Royer Lake watershed. The high concentrations of nitrate being received by these streams is in part a result of high inorganic inputs from runoff of nitrogen-containing sedimentary rock formations (Wetzel, 1983). Additionally, Wetzel (1983) states that regions bordering the Great Lakes receive large contributions of nitrogen from atmospheric sources (i.e., precipitation and dry fallout).

There have been limited investigations by the LaGrange County Board of Health into the possibility of septic field leachate reaching Fish and Royer Lakes. The near-shore areas of both lakes have been developed primarily within the last 40 years. All of the residences utilize septic systems that, in many

TABLE 3-1. **Summary of historical data available for Fish and Royer Lakes.**

FISH LAKE

DATE	AGENCY	DESCRIPTION
1946-58	USGS	Lake discharge measurements (cfs)
1972	IDNR	Fish Management Report
1973	ISBH	Lake Survey Data
1974	IDNR	Fish Management Report
1977	ISBH	Lake Survey Data
1978	ISBH	Lake Survey Data
1978	IDNR	Fish Management Report
1985	IDNR	Fish Management Report
1987-89	USGS	Lake gage height (ft.)
1989	LCHD	*Survey of Twenty-Four Lakes in LaGrange County, Indiana*
1989	LCHD	Lake Survey Notes

ROYER LAKE

DATE	AGENCY	DESCRIPTION
1973	ISBH	Lake Survey Data
1973	IDNR	Fish Management Report
1974	IDNR	General water quality data
1976	ISBH	Tributary water quality data (unnamed and unidentified on data sheets)
1977	ISBH	Lake Survey Data
1978	IDNR	Fish Management Report
1985	IDNR	Fish Management Report
1989	LCHD	*Survey of Twenty-Four Lakes in LaGrange County, Indiana*
1989	LCHD	Lake Survey Notes

cases, may be located at or below the water table. Although the LaGrange County Board of Health conducted dye tests on septic systems prior to 1987, the results were inconclusive (pers. comm., Bill Grant, 1989).

3.1.2 Fish Population Surveys

Fish population surveys were conducted by the IDNR on Fish Lake in 1972, 1974, 1978 and 1985. Until 1973, Fish Lake had been stocked with rainbow trout (*Salmo gairdnerii*). Studies in 1972 indicated that water quality was only marginal for cold-water species. Due to the lack of suitable water quality and public interest, Fish Lake was removed from the annual trout stocking program for 1973. A

TABLE 3-2. Water quality data collected from tributaries to Fish and Royer Lakes by the LaGrange County Health Department.

Fish Lake - East Tributary

DATE	TP(mg/l)*	PO_4 (mg/l)**	NO_3 (mg/l)**
16 Jun 1988	0.13	0.07	4.60
17 Jun 1988		0.10	2.70
07 Jul 1988	0.14		
11 Jul 1988	0.06		
14 Jul 1988	0.01		

Royer Lake - East Tributary

DATE	TP(mg/l)*	PO_4 (mg/l)**	NO_3 (mg/l)**
23 Jun 1988		0.10	2.40
07 Jul 1988	0.22		
14 Jul 1988	0.57		
15 Aug 1988		0.20	1.30
18 Aug 1988	0.16		
17 Oct 1988	0.20		

Royer Lake - South Tributary

DATE	TP(mg/l)*	PO_4 (mg/l)**	NO_3 (mg/l)**
07 Jul 1988	0.35		
22 Jul 1988	0.31		
15 Aug 1988	0.39	0.20	1.30
18 Aug 1988	0.29		

* - analysis performed at Tri-State University, Angola, IN
** - analysis performed by LaGrange County Health Department

self-sustaining warm-water fishery was reported in 1974 and 1978 fish management reports for the lake. Species documented in these reports and their relative abundance are listed in Table 3-3.

An interesting observation reported in the 1985 survey was that no bluegill (*Lepomis macrochirus*) or largemouth bass (*Micropterus salmoides*) in the Age Class IV+ or older were collected. The survey report stated that the fish population appeared to be one that had experienced a fish kill, although none had been reported. The survey recommended installing brush pile fish attractors as a management tool.

Fish population surveys were conducted by the IDNR on Royer Lake in 1973, 1978 and 1985. The results of these surveys indicated that Royer Lake supports a self-sustaining warm-water fishery. Fish species documented in these surveys, and their relative abundance, are listed in Table 3-4.

TABLE 3-3. Fish species and their relative abundance in Fish Lake (source IDNR Fish Management Reports).

COMMON NAME	SCIENTIFIC NAME	1974	1978	1985
bluegill	*Lepomis macrochirus*	24.9%	66.4%	21.5%
largemouth bass	*Micropterus salmoides*	16.4%	4.1%	16.7%
warmouth	*Lepomis gulosus*	10.7%	2.3%	2.7%
yellow bullhead	*Ictalurus natalis*	8.7%	5.7%	11.8%
yellow perch	*Perca flavescens*	7.6%	5.4%	12.6%
green sunfish	*Lepomis cyanellus*	7.1%	1.1%	18.8%
pumpkinseed	*Lepomis gibbosus*	6.8%	6.8%	2.2%
black crappie	*Pomoxis nigromaculatus*	3.4%	0.2%	
lake chubsucker	*Erimyzon sucetta*	2.8%	1.7%	1.9%
golden redhorse	*Moxostoma erythrurum*	2.2%	0.7%	3.4%
redear sunfish	*Lepomis microlophus*	2.2%		
white sucker	*Catostomus commersonii*	1.7%	2.2	4.1%
grass pickerel	*Esox americanus*	1.7%	0.3%	1.0%
brown bullhead	*Ictalurus nebulosus*	1.4%	0.1%	1.0%
bowfin	*Amia calva*	1.4%	0.3%	0.7%
northern pike	*Esox lucius*	0.8%	0.1%	0.2%
golden shiner	*Notemigonus crysoleucas*		1.1%	1.0%
common carp	*Cyrprinus carpio*		0.5%	0.2%
white crappie	*Pomoxis annularis*		0.3%	
spotted gar	*Lepisosteus oculatus*		0.2%	
rock bass	*Ambloplites rupestris*		0.1%	
spotted sucker	*Minytrema melanops*			0.2%

3.1.3 Aquatic Plants

Included in the IDNR fisheries survey reports was a list of aquatic plant species commonly found in both lakes. The results of the surveys conducted in Fish and Royer Lakes are presented in Tables 3-5 and 3-6, respectively. A maximum of 10 plant species were identified in Fish Lake and 11 species in Royer Lake on any particular survey date.

3.1.4 Erodible Soils

The Soil Conservation Service (SCS) has done extensive soil mapping around Fish and Royer Lakes. Highly erodible soils cover approximately 690 acres (19 percent) of the Royer Lake watershed, and 700 acres (17 percent) of the Fish Lake watershed (Grant, 1989). Highly erodible soils are contiguous with the western shore of Royer Lake and occur throughout the drainage basins of each lake. The majority of highly erodible soils are found in the eastern and southwestern portion of these watersheds, especially near the southern and northeastern inlets to Royer Lake and the southeastern shore of Fish Lake.

TABLE 3-4. **Fish species and their relative abundances in Royer Lake (source IDNR Fish Management Reports).**

COMMON NAME	SCIENTIFIC NAME	1974	1978	1985
bluegill	*Lepomis macrochirus*	35.2%	43.3%	47.0%
largemouth bass	*Micropterus salmoides*	19.7%	4.1%	12.1%
yellow bullhead	*Ictalurus natalis*	10.8%	24.5%	8.0%
white sucker	*Catastomus commersonii*	7.7%	6.3%	10.0%
pumpkinseed	*Lepomis gibbosus*	6.9%	4.2%	4.2%
spotted gar	*Lepisosteus oculatus*	4.2%	0.9%	0.4%
warmouth	*Lepomis gulosus*	3.8%	1.6%	1.8%
lake chubsucker	*Erimyzon sucetta*	3.1%	3.1%	1.5%
black crappie	*Pomoxis nigromaculatus*	2.7%	1.6%	0.7%
bowfin	*Amia calva*	1.1%	1.1%	1.5%
grass pickerel	*Esox americanus*	1.1%	0.5%	0.4%
yellow perch	*Perca flavescens*	0.7%	3.1%	7.2%
northern pike	*Esox lucius*	0.7%	0.3%	
golden redhorse	*Moxostoma erythrurum*	0.4%	0.8%	1.1%
green sunfish	*Lepomis cyanellus*	0.4%		
brown bullhead	*Ictalurus nebulosus*	0.4%	1.7%	1.1%
redear sunfish	*Lepomis microlophus*	0.4%		
golden shiner	*Notemigonus crysoleucas*	P	0.8%	3.3%
brook silverside	*Labidesthes sicculus*	P	C	
common carp	*Cyprinus carpio*		1.4%	0.2%
rock bass	*Ambloplites rupestris*		0.3%	
pumpkinseed X bluegill		0.2%		
white crappie	*Pomoxis annularis*		0.2%	
spotted sucker	*Minytrema melanops*			0.2%

Note: P = present; C = common

3.1.5 Land Use

Land use in the Fish and Royer Lake Watershed is approximately 62 percent agricultural. The agricultural practices are primarily crop farming although some animal operations such as dairy and hog farming are also present in the watersheds. Data obtained from the Conservation Technology Information Center (CTIC) for 1984 and 1988 showed the majority of the cropland in LaGrange County to be used for corn production. Soybeans and small grain crops such as wheat, rye, barley and oats comprised the majority of the remaining cropland. In 1984, conservation tillage practices were utilized on 30 percent of the active cropland. The primary type of conservation tillage practiced in 1984 was mulch-till, where the soil surface is disturbed just prior to planting and weed control is accomplished using a combination of herbicides and/or cultivation. CTIC data for 1988 indicate conservation tillage was practiced on 50 percent of the active cropland. Mulch-till was still the primary type of conservation tillage practiced. No-till accounted for 10 percent of the conservation tillage utilized. No-till conservation tillage leaves the soil undisturbed prior to planting. Planting is done in a narrow seedbed created by a planter or drill. Weed control is accomplished through the use of herbicides.

TABLE 3-5. Historical data on aquatic plant species present in Fish Lake (source IDNR Fish Management Reports).

COMMON NAME	SCIENTIFIC NAME	1974	1978	1985
filamentous algae		X		
coontail	*Ceratophyllum demersum*		X	X
stonewarts	*Chara* spp.	X	X	X
spiked rush	*Eleocharis* spp.	X	X	X
milfoil	*Myriophyllum* spp.		X	X
spatterdock	*Nuphar* spp.	X	X	X
pickerelweed	*Pontederia cordata*	X	X	X
leafy pondweed	*Potamogeton foliosus*	X	X	X
Richardson pondweed	*Potamogeton richardsonii*		X	X
sago pondweed	*Potamogeton pectinatus*	X	X	X
common cattail	*Typha latifolia*	X	X	X

TABLE 3-6. Historical data on aquatic plant species present in Royer Lake (source IDNR Fish Management Reports).

COMMON NAME	SCIENTIFIC NAME	1974	1978	1985
button bush	*Cephalanthus occidentalis*	X	X	X
coontail	*Ceratophyllum demersum*	X	X	X
stonewarts	*Chara* spp.	X	X	X
swamp loosestrife	*Decodon verticillatus*	X	X	X
spiked rush	*Eleocharis* spp.	X	X	X
water willow	*Justicia americana*	X		
milfoil	*Myriophyllum* spp.	X	X	X
spatterdock	*Nuphar* spp.	X	X	X
water lily	*Nymphaea* spp.	X		
pickerelweed	*Pontaderia cordata*	X	X	X
leafy pondweed	*Potamogeton foliosus*	X	X	X
sago pondweed	*Potamogeton pectinatus*	X		
water buttercup	*Ranunculus* spp.		X	X
common cattail	*Typha latifolia*	X	X	X

3.1.6 Significant Natural Areas and Endangered or Important Species

The Division of Nature Preserves, IDNR, has identified a significant natural area and several rare and threatened species in the Fish and Royer Lakes watershed. The Division of Nature Preserves has a database of information pertaining to these significant areas and species, and can identify their locations by latitude and longitude coordinates on U.S.G.S. quadrangle maps. The Grass Lake natural area is located within the Fish Lake watershed boundaries. A list of the identified species and wetlands located in the Fish and Royer Lake watersheds are identified in Table 3-7.

TABLE 3-7. **Identified significant natural areas and rare/threatened species located in the Fish and Royer Lakes watershed.**

U.S.G.S. Quadrangle	Mongo		
Natural Area	LaGrange County Nature Center (LCNC) - Land and Water Conservation Fund Area 458		
Latitude/Longitude	**Species Common Name**	**Scientific Name**	**Status**
41°37'52"N/85°19'17"W	Pink Lady's Slipper	*Cypripedium acaule**	Watch list

U.S.G.S. Quadrangle	Wolcottville		
Natural Area	LCNC - Land and Water Conservation Fund Area 458		
Latitude/Longitude	**Species Common Name**	**Scientific Name**	**Status**
41°37'25"N/85°19'40"W	Fewflower Spikerush	*Eleocharis pauciflora**	Rare
41°37'25"N/85°19'40"W	Marsh Arrow-Grass	*Triglochin palustre**	Threatened
41°35'09"N/85°18'44"W	Downy Yellow Violet	*Viola pubsecens*	Watch list

U.S.G.S. Quadrangle	Wolcottville		
Natural Area	Grass Lake Natural Area.		
Latitude/Longitude	**Species Common Name**	**Scientific Name**	**Status**
41°37'02"N/85°17'30"W	Forested Fen	Not Applicable	Wetland
41°37'02"N/85°17'30"W	Red Baneberry	*Actaea rubra*	Threatened
41°37'02"N/85°17'30"W	Cuckoo Flower	*Cardamine pratensis**	Wetland
41°37'12"N/85°17'48"W	Spotted Turtle	*Clemmys guttata*	Threatened
41°37'12"N/85°17'48"W	Fewflower Spikerush	*Eleocharis pauciflora*	Rare
41°37'12"N/85°17'48"W	Smooth Gooseberry	*Ribes hirtellum*	Rare
41°37'12"N/85°17'48"W	Autumn Willow	*Salix serissima*	Threatened
41°37'12"N/85°17'48"W	Marl Beach	Not Applicable	Wetland
41°37'12"N/85°17'33"W	Buckmoth	*Hemileuca sp.3*	Watch list

* Observed prior to 1960

3.2 LAKE SURVEY RESULTS

The findings of the Fish and Royer lake surveys are presented in the following paragraphs. Components of the investigation included in-situ, chemical, and biological water quality measurements; aquatic macrophyte mapping; and bathymetric mapping. Summertime conditions in the lakes were characterized based on the survey data and calculations of trophic state indices.

3.2.1 In-Situ Water Quality

In-situ water quality measurements collected at Fish Lake are listed in Table 3-8 and presented graphically in Figures 3-1a through 3-1c. These data indicate that Fish Lake was thermally stratified when the

TABLE 3-8. Results of in-situ water quality sampling conducted at Fish Lake on 24 August 1989.

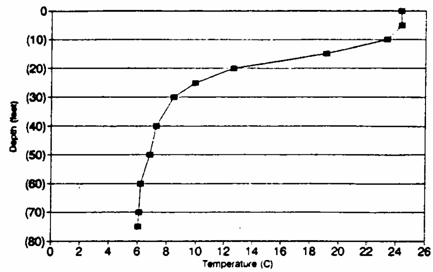
Depth (feet)	Depth (m)	Temperature (°F)	Temperature (°C)	DO (mg/l)	pH
0	0	75.8	24.3	10.1	8.44
5	1.5	75.8	24.3	10.1	8.44
10	3.1	74.0	23.4	8.5	8.35
15	4.6	66.4	19.1	0.8	7.61
20	6.1	54.7	12.6	0.2	7.62
25	7.6	49.9	9.9	0.1	7.61
30	9.1	47.2	8.4	1.0	7.63
40	12.2	45.1	7.3	1.3	7.65
50	15.2	44.3	6.8	1.1	7.66
60	18.3	43.1	6.2	0.1	7.62
70	21.3	42.9	6.1	0.1	7.61
75	22.9	42.8	6.0	0.1	7.60

Secchi Disk Transparency: 4.9 feet (1.5 m)
Light Transmission at 3 feet (0.91m): 43.5%

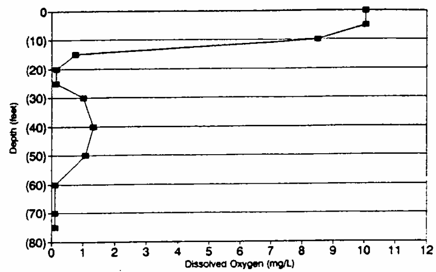
samples were collected. The lake thermocline was located between 10 and 20 feet (3.0 and 6.1 m), as indicated by the maximum rate of decrease in the temperature at those depths (Figure 3-1a).

The shape of the DO profile measured at Fish Lake (Figure 3-1b) is best described as clinograde, with well-oxygenated waters near the surface (i.e., epilimnion), tapering dramatically toward anoxia in the 15 to 20 foot (4.6 to 6.1 m) depth range. This condition is usually observed during periods of thermal stratification (generally in summer and winter) when oxygen consumption exceeds oxygen production in the bottom waters (i.e., hypolimnion). Because water circulation is reduced during stratification, less oxygen can be distributed to the hypolimnion from the surface. A slight increase in DO concentration was observed in Fish Lake at the 30 to 60 foot (9.1 to 18.3 m) depth range and can be termed an "oxygen maximum." The phenomenon is common in stratified waters and is the result of oxygen produced by algal populations that develop more rapidly than they sink. The occurrence of oxygen maxima most often coincides with peak growth of rooted and submersed aquatic macrophytes where oxygen enriched waters dissipate into the metalimnion layer (Wetzel, 1983).

Temperature (C)



Dissolved Oxygen (mg/l)



pH

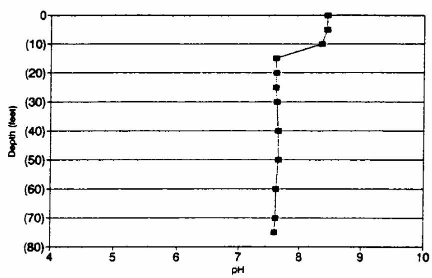


FIGURE 3-1. Graphical representations of in-situ water quality data taken at Fish Lake.

Values for pH ranged between 8.4 (surface) and 7.6 (bottom) as displayed in Figure 3-1c. The majority of open lakes have a pH range between 6 and 9. Such lakes are regulated by a natural carbonate buffering system. The distribution of pH is influenced by photosynthetic utilization of carbon dioxide (CO_2) in the trophogenic zone and respiratory generation of CO_2 throughout the water column and sediments. If the accumulation of CO_2 exceeds oxygen consumption and the hypolimnion becomes anaerobic, the pH will decrease markedly.

Water clarity was below average for most Indiana lakes, with a Secchi disk depth of 4.92 feet (1.5 m). This depth is within the 36th percentile of 400 previously studied Indiana lakes (IDEM, 1986). Light transmission was 43.5% at a depth of 3 feet (0.9 m).

In-situ water quality measurements for Royer Lake are listed in Table 3-9 and presented graphically in Figures 3-2a through 3-2c. Royer Lake was also thermally stratified (Figure 3-2a) with the lake thermocline located between 10 and 20 feet (3.0 and 6.1 m). The DO concentration was greatly reduced beneath the thermocline (Figure 3-2b). Again, this condition is typical of eutrophic lakes with an anaerobic hypolimnion. Measurements of pH were within the range of a typical open lake (Figure 3-2c). Secchi disk depth was 5.9 feet (1.8 m). This depth is within the 50th percentile of 400 previously studied Indiana lakes (IDEM, 1986). Light transmission was 48.5% at a depth of 3 feet (0.9 m).

TABLE 3-9. Results of in-situ water quality sampling conducted at Royer Lake on 24 August 1989.

Depth (feet)	Depth (m)	Temperature (°F)	Temperature (°C)	DO (mg/l)	pH
0	0.0	76.2	24.6	10.3	8.50
3	0.9	76.3	24.6	10.2	8.50
5	1.5	76.0	24.5	10.0	8.48
10	3.1	73.2	22.9	7.4	8.12
15	4.6	60.8	16.0	0.2	7.60
20	6.1	51.2	10.7	0.2	7.61
25	7.6	47.7	8.7	0.1	7.62
30	9.1	45.8	7.6	0.1	7.61
35	10.7	45.1	7.3	0.1	7.59
40	12.2	44.3	6.8	0.1	7.54
45	13.7	43.8	6.5	0.1	7.47
50	15.2	43.5	6.4	0.1	7.46

Secchi Disk Transparency: 5.91 feet (1.80 m)

Light Transmission at 3 feet (0.91m): 48.50%

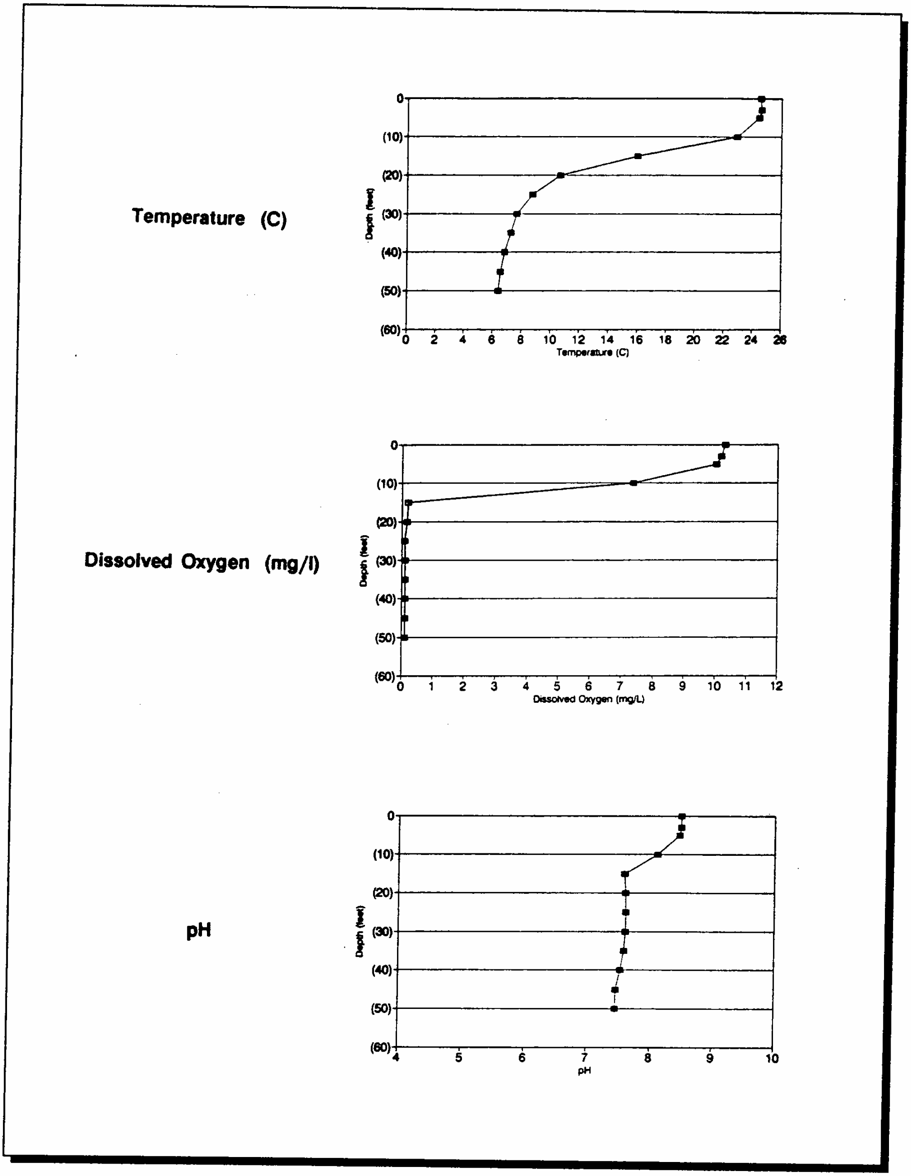


FIGURE 3-2. Graphical representations of in-situ water quality data taken at Royer Lake.

3.2.2 Chemical Water Quality

Chemical water quality measurements for Fish Lake water samples are listed in Table 3-10. The values obtained for chlorophyll a (Chl a) were within the range of those found in both mesotrophic and eutrophic lakes (Wetzel, 1983). In all three samples, the fecal coliform cell concentrations were within acceptable levels for public swimming waters (i.e., <400 organisms per 100 ml). The ratio of total nitrogen (TN) to total phosphorus (TP), commonly referred to as N:P, at depths above the thermocline was above 90:1.

TABLE 3-10. Results of water chemistry sampling conducted at Fish Lake on 24 August 1989.

Depth (ft)	(m)	Chla (mg/m^3)	Fecal (#/100ml)	N-NH_4 (mg/l)	NO_3 (mg/l)	TKN (mg/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)	N:P ratio
0.0	0.0	4.81	20	<0.005	1.755	0.710	0.024	0.027	2.50	91
40.0	12.2	0.00	0	<0.005	2.114	0.583	<0.005	<0.011	0.25	245
55.0	16.8	3.84	0	<0.005	2.369	0.590	<0.005	<0.011	0.50	269

TN is calculated by adding total Kjeldahl nitrogen (TKN) and nitrate (NO_3) values. N:P ratios above 20:1 are characteristic of lakes where phosphorus is the limiting nutrient. Typically, land and atmospheric based sources provide more nitrogen than can be fully utilized by photosynthesis with a finite supply of phosphorus. As a result, phosphorus is rapidly incorporated in phytoplanktonic algae and bacteria in the epilimnion. The ammonia concentrations were negligible, which is not uncommon in unpolluted waters. TKN concentrations were approximately the same in the surface and both mid-depth samples. It is assumed that higher concentrations would have been observed at the sediment-water interface due to anoxic conditions. Total suspended solids decreased with depth as would be expected due to the settling of solids. The concentrations of nitrate increased towards the bottom which is not common in anoxic waters. However, the presence of an oxygen maximum below the thermocline, and noted above, indicated that the waters sampled were not anoxic; at least 1.0 mg/l of dissolved oxygen was present at the depths associated with the mid-depth and bottom samples. Thus, the nitrate concentrations are probably the result of nitrifying bacteria decomposing organic material. No interpretations can be made regarding the water quality at the hypolimnion as the sample taken at 55 feet (16.8 m) is not considered indicative of the lake bottom.

Similar analyses were performed for water quality in Royer Lake. Results of in-lake samples collected at station SL_{WQ} are listed in Table 3-11. The chlorophyll a concentrations at all depths of the lake were in the range of those values found in both mesotrophic and eutrophic lakes (Wetzel, 1983). The fecal coliform cell concentrations were well within acceptable limits for swimming waters. The high concentration of ammonia at 50 feet (15.2 m) was attributed to anaerobic conditions at that depth since ammonia concentrations are typically elevated in poorly oxygenated waters. The nitrate (NO_3) concentrations decreased in the hypolimnion as a result of denitrification processes that occur in anaerobic

TABLE 3-11. Results of water chemistry sampling conducted at Royer Lake on 24 August 1989.

Depth (ft)	Depth (m)	Chla (mg/m^3)	Fecal (#/100ml)	$N\text{-}NH_4$ (mg/l)	NO_3 (mg/l)	TKN (mg/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)	N:P ratios
0.0	0.0	8.54	6	<0.005	0.856	0.764	<0.005	<0.011	2.25	147
25.0	7.6	4.81	2	1.040	0.121	1.479	0.023	0.039	2.33	41
50.0	15.2	2.24	2	2.400	0.122	2.400	0.293	0.306	3.33	8

environments. Relatively high concentrations of TKN were observed near the sediment-water interface. TKN represents organically-bound nitrogen and elevated concentrations are representative of the high levels of organic matter present in the hypolimnion. Total phosphorus (TP) concentrations in Royer Lake were typical of mesotrophic or slightly eutrophic waters. Increased total and soluble phosphorus content near the bottom is common in eutrophic lakes with strongly clinograde oxygen profiles (Wetzel, 1983). Much of the increase was probably due to soluble orthophosphorus (OP) near the sediment-water interface, as 83% of the TP near the lake bottom was in the OP form (Table 3-11). The N:P ratios at the thermocline and above were between 41:1 and 147:1, respectively, indicating that Royer is phosphorus limited.

Results of storm event sampling are presented in Table 3-12 and Table 3-13. The highest solids concentrations were observed in the FL-2 tributary site east of Fish Lake. This finding reflects the predominance of row-crop agriculture in the large sub-basin draining into the lake via this tributary. Elevated solids loading is especially characteristic of erosion-prone areas associated with row-crop practices. By reviewing the relative contributions of total phosphorus and ortho phosphorus (TP and OP, respectively), it can be seen that the overwhelming majority of phosphorus entering Fish Lake from FL-2 was sediment bound (i.e., OP was nearly negligible). Nutrient inputs from FL-3 were moderate. The moderately high concentrations of TKN found in the tributaries were probably the result of organic sediment flushing during the storm event. The data from the outlet stream FL-1 consisted of very low to moderate nutrient concentrations.

TABLE 3-12. Results of storm event sampling in the outlet and tributaries to Fish Lake on 14 September 1989.

Station	Time Collected	$N\text{-}NH_4$ (mg/l)	NO_3 (mg/l)	TKN (mg/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)
FL-1	16:05	0.020	1.609	1.070	<0.005	<0.001	4.44
FL-2	15:00	0.018	3.712	1.020	0.011	0.068	12.00
FL-3	15:45	0.031	0.518	1.165	0.005	0.011	4.20

Phosphorus loading to Royer Lake from streams RL-4 and RL-5 was primarily in the dissolved form (i.e., OP). TKN concentrations were moderately high for both tributaries. The high concentration of TSS

TABLE 3-13. Results of storm event sampling in tributaries to Royer Lake on 14 September 1989.

Station	Time Collected	$N\text{-}NH_4$ (mg/l)	NO_3 (mg/l)	TKN (mg/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)
RL-4	15:05	<0.005	2.928	1.580	0.184	0.292	29.20
RL-5	15:25	0.048	2.548	1.458	0.106	0.117	2.00

found in the tributary east of Royer Lake at site RL-4 reflects high solids loading. High levels of nitrate were present in both RL-4 and RL-5 storm samples indicate high contributions from runoff and atmospheric sources (Section 3.1.1).

3.2.3 Phytoplankton

Results of phytoplankton identification and enumeration revealed a fairly diverse algal community in both Fish and Royer Lakes. The phytoplankton communities were numerically dominated by the Cyanophyta, commonly referred to as blue-greens (Figures 3-3 and 3-4). In Fish Lake, a total of 26 species in 4 classes was observed (Table 3-14). At a depth of 5 feet (1.5 m), *Microcystis flos-aquae* and *Chroococus disperses* were prevalent while at 20 feet (13.7 m), *Lyngbya Birgei* and *Aphanocapsa pulchra* dominated. In Royer Lake, a total of 38 species in 5 classes was represented (Table 3-15). *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* dominated at 5 feet (1.5 m) and at 20 feet (13.7 m) *Lyngbya Birgei* and *Microcystis aeruginosa* were most abundant.

Microcystis, Aphanizomenon, and *Anabaena* are associated with advanced eutrophic conditions. All three species are known to produce lethal toxins under certain conditions and can be associated with summer fish kills (Cole, 1979). *Chroococus disperses* and *Lyngbya Birgei* are common in hard and semi-hard water lakes. *Lyngbya* is associated with the three previously mentioned species, however, it does not play an important role in water bloom disturbances because it fails to form floating masses (Prescott,1982).

3.2.4 Bathymetry

Review of the bathymetric data collected for this project indicated that the maximum depth of Fish Lake was 78 feet (23.8 m) as shown in Figure 3-5. The mean depth was 40.5 feet (12.3 m) and the volume was 1.83×10^8 cubic feet (5.17×10^6 m^3).

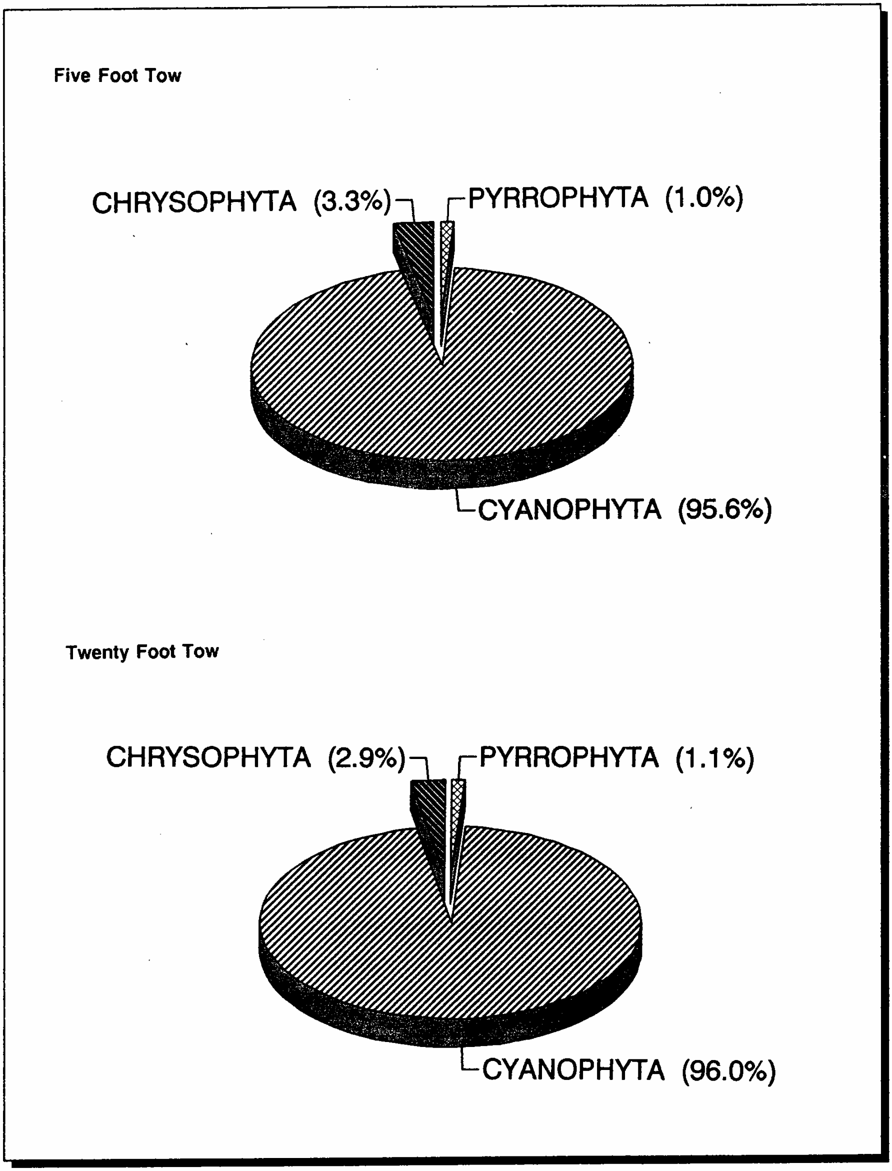


FIGURE 3-3. **Graphical results of phytoplankton tows taken in Fish Lake on 24 August 1989.**

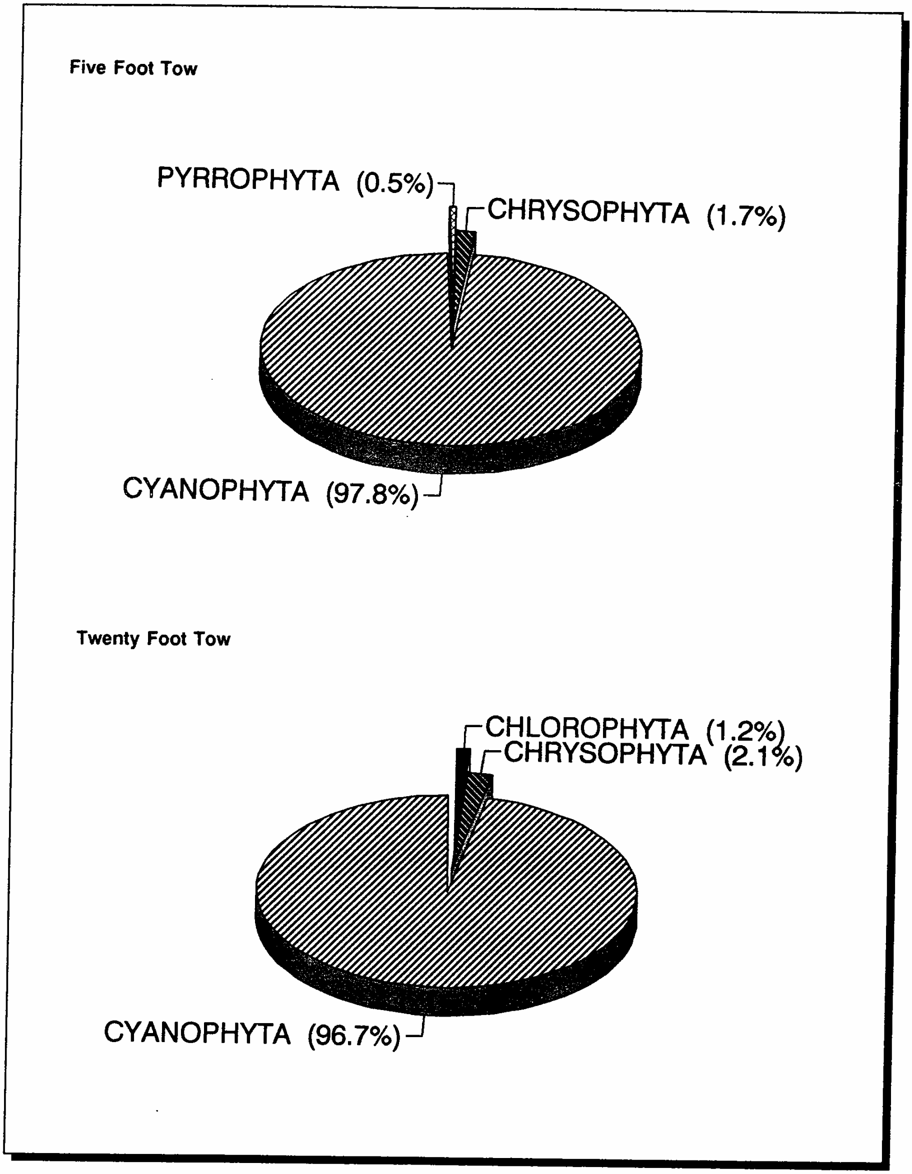


FIGURE 3-4. **Graphical results of phytoplankton tows taken in Royer Lake on 24 August 1989.**

TABLE 3-14. Results of Fish Lake phytoplankton identification and enumeration samples collected on 24 August 1989.

	Surface		Thermocline	
Depth of Sample (feet)(m)	5.0	1.5	19.8	6.0
Sampled Water Volume (feet^3)(l)	3.6	102.0	14.2	402.1
SPECIES	NUMBER OF CELLS (count in millions)			
Chlorophyta (greens)				
Chlamydomonas pertyi	*			
Chlamydomonas sp				
Closteriopsis longissima				
Dinobryon divergens				
Pediastrum simplex	*			
Sphaerocystis Schroeteri	*			
green flagellates	.141			
green monads	.424			
Chrysophyta (diatoms, chrysophytes, etc.)				
Cyclotella sp				
Dinobryon sociale				
Fragilaria crotonensis	4.8		3.28	
Melosira sp			.82	
Navicula sp	*			
Synedra sp	*		.117	
centric diatoms < 10u	.141			
pennate diatoms > 25u				
Pyrrhophyta (yellow-browns)				
Ceratinium hirundella	1.27		1.40	
Cryptomonas erosa	.141		.117	
Dinobryon divergens	.141		.117	
Cyanophyta (blue-greens)				
Anabaena flosaquae	7.49			
Anabaena planctonica (poor shape)	1.70		.468	
Aphanocapsa delicatissima	2.54			
Aphanocapsa pulchra	7.77		15.3	
Aphanizomenon flosaquae	3.81		.468	
Chroococus disperses	21.8			
Lyngbya Birgei	19.5		106	
Merismopedia tenuissima	4.24		5.62	
Microcystis flosaquae	35.3			
Oscillatoria planctonica	*			
Oscillatoria tenuis	.706		9.84	
blue-green monads	37.2		1.40	
blue-green filaments			1.52	
Total Cells Per Sample (counts in millions)	149		146	
Total Cells Per Volume for Water Towed (#/l)	1462200		363090	

*Species observed but not part of count. Note: Thermocline sample was contaminated with bacteria; sample was in poor shape.

TABLE 3-15. Results of Royer Lake phytoplankton identification and enumeration samples collected on 24 August 1989.

	Surface		Thermocline	
Depth of Sample (feet)(m)	5.0	1.5	20.0	6.1
Sampled Water Volume (feet^3)(l)	3.6	102.0	14.4	407.8
SPECIES	NUMBER OF CELLS (count in millions)			
Chlorophyta (greens)				
Chlamydomonas globosa	.156			
Closteriopsis longissima			.128	
Coelastrum microporum	*			
Gloeocystis gigas	*		1.02	
Gloeocystis sp				
Oocystis pusilla			*	
Pandorina morum			*	
Sphaerocystis Schroeteri	*		.384	
Stayrastryn sp	*			
Chrysophyta (datoms, chrysophytes, etc.)				
Dinobryon divergens	.078		.128	
Dinobryon sociale			*	
Fragilaria crotonensis	1.13		1.02	
Melosira granulata	*		.768	
Navicula sp	.156			
centric diatoms < 10u			.640	
pennate diatoms > 25u	.078		.128	
Euglenop[hyta (euglenoids)				
Euglena sp	.039			
Trachelmonas sp	*			
Pyrrhophyta (yellow-browns)				
Ceratium hirundinella	.156		.128	
Cryptomonas erosa	.078		.256	
Cryptomonas massonii			.128	
Cryptomonas ovata	*			
Cryptomonas phaseolus	.234		*	
Cynophyta (blue-greens)				
Anabaena flosaquae	10.5		.768	
Anabaena planctonica	3.28		8.06	
Aphanizomenon flosaquae	18.3		1.92	
Aphanocapsa pulchra			*	
Aphanothece gelatinosa	.703			
Coelosphaerium kuetzingianum	*			
Chroococus disperses			2.94	

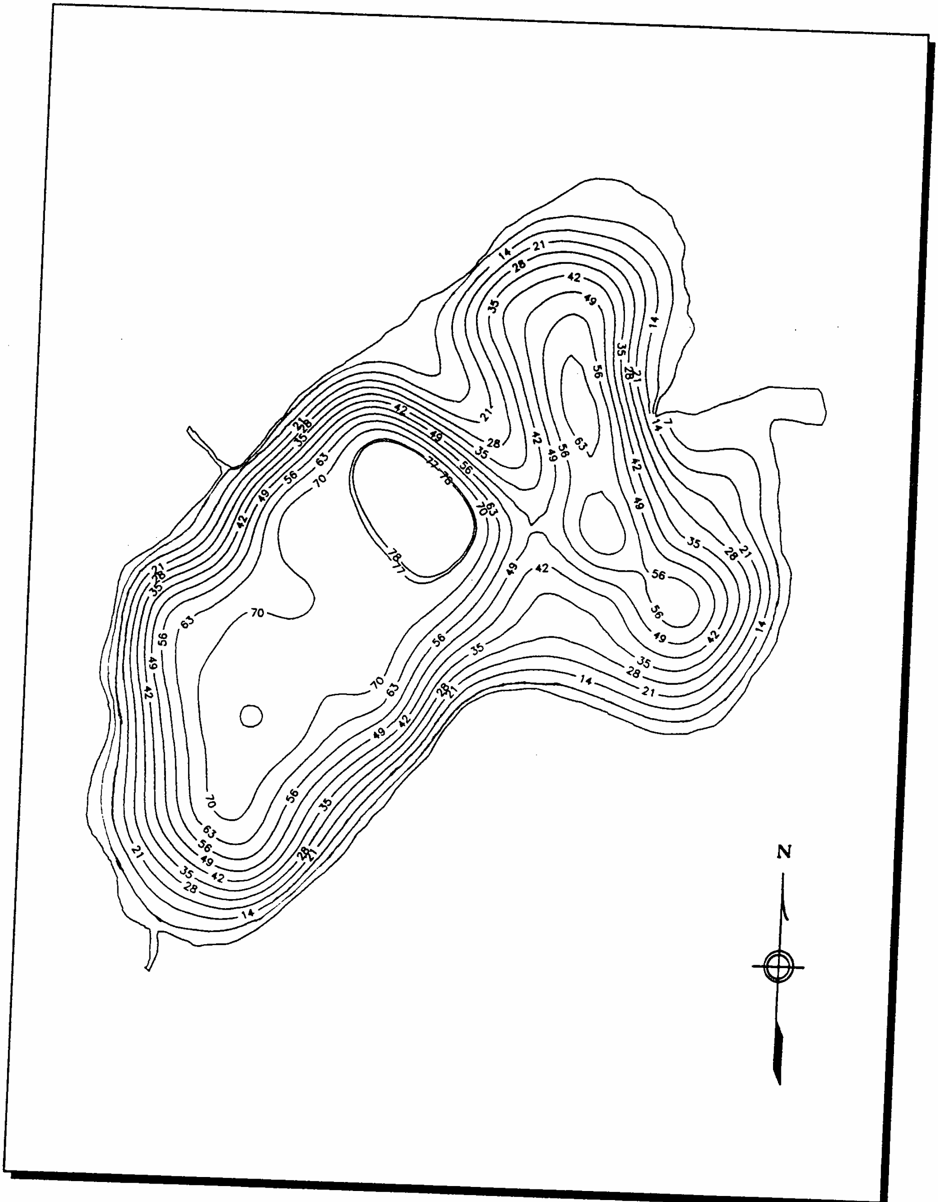


FIGURE 3-5. **Bathymetric map of Fish Lake in 1989. Depths are shown in seven foot contours.**

TABLE 3-15. Concluded.

SPECIES	Surface	Thermocline
	NUMBER OF CELLS (count in millions)	
Merismopedia tenuissima		2.56
Microcystis aeruginosa	6.32	32.0
Microcystis flosaquae		*
Oscillatoria planctonica	.312	2.43
Oscillatoria tenuis	3.90	3.58
Oscillatoria sp		6.14
blue-green monads	41.5	10.9
TOTAL CELLS PER SAMPLE (count in millions)	87.15	127.23
TOTAL CELLS PER VOLUME OF WATER TOWED (#/l)	855250	311990

*Species observed but not part of the count.

The maximum depth of Royer Lake was 59 feet (21.7 m), as shown in Figure 3-6. The volume of the lake was 6.01 X 10^7 cubic feet (1.70 X 10^6 m^3) and the mean depth was 23.6 feet (7.2 m).

3.2.5 Aquatic Vegetation

The aquatic vegetation survey documented a wide diversity of macrophytes for both Fish and Royer Lakes (Tables 3-16 and 3-17, respectively). The dominant emergent species in Fish Lake were soft rush (*Juncus effusus)* and common cattail (*Typha latifolia*). The predominant submergent species throughout the lake were coontail (*Ceratphyllum demersum*), water milfoil (*Myriophyllum spicatum*), and American pondweed (*Potamogeton americanus*). The most common floating species along the shores of Fish Lake were yellow and white water lilies (*Nuphar variegatum* and *Nymphaea ordorata*, respectively). Aquatic plant coverage maps for Fish Lake are presented in Figures 3-7a through 3-7c.

In Royer Lake, the dominant emergent species were arrowhead (*Sagittaria* sp.) and common cattail. The predominant submergent plant species were water milfoil, pickerel weed (*Pontederia cordata*), stonewarts (*Chara* sp.), and coontail. Of the floating species, white and yellow water lilies were most common and occurred predominantly along the shores of the lake. Duckweed (*Lemna minor*)was present in the southern portion of the lake. Aquatic plant coverage maps for Royer Lake are presented in Figures 3-8a through 3-8c.

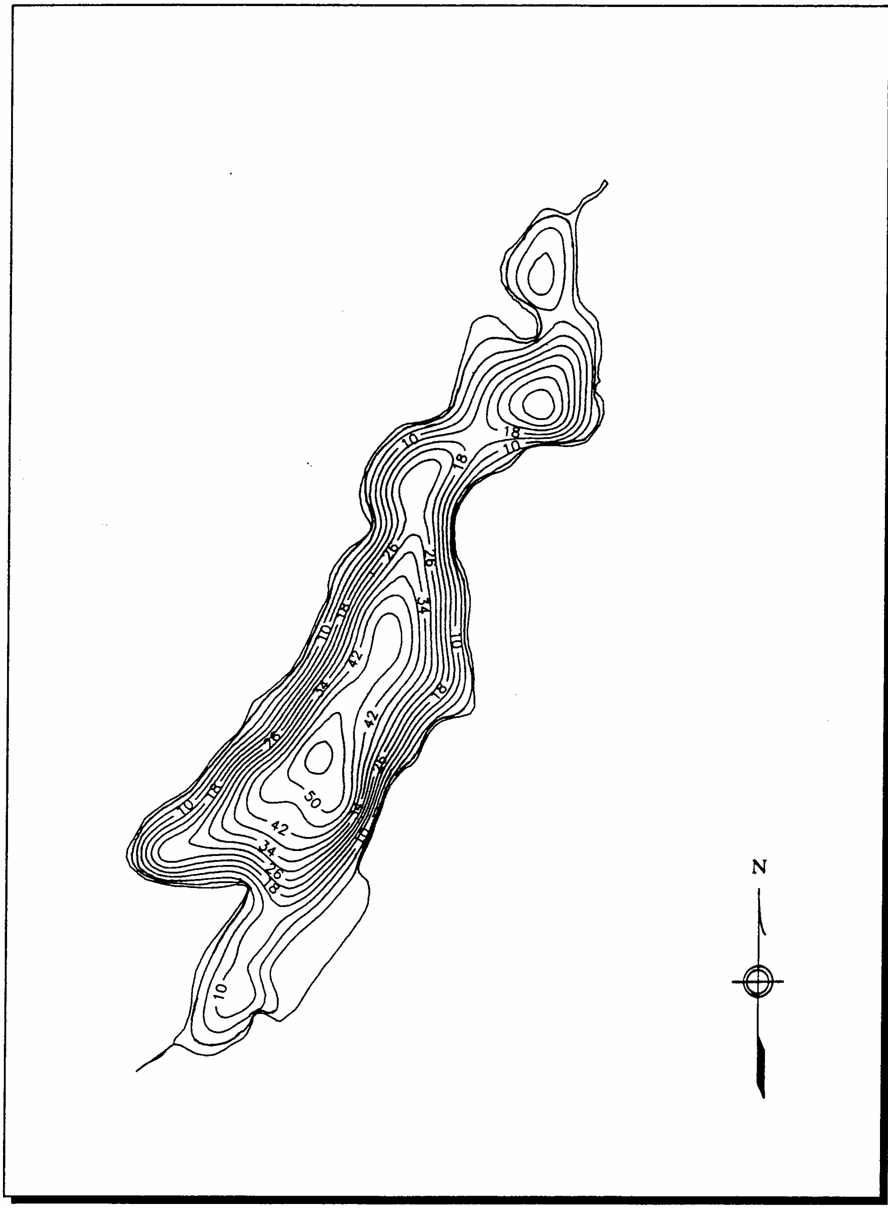


FIGURE 3-6. Bathymetric map of Royer Lake in 1989. Depths shown in four foot contours.

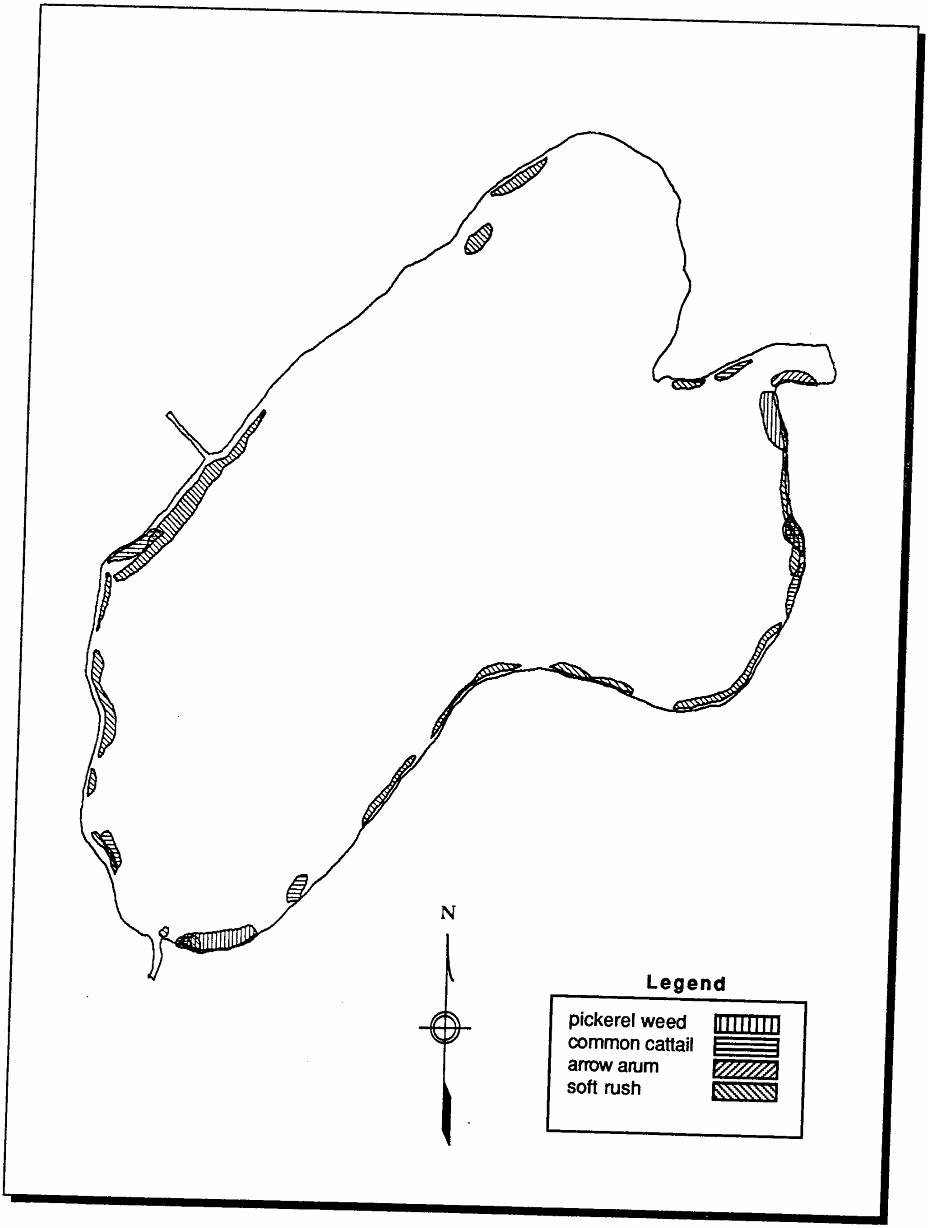


FIGURE 3-7a. Emergent macrophyte distribution in Fish Lake.

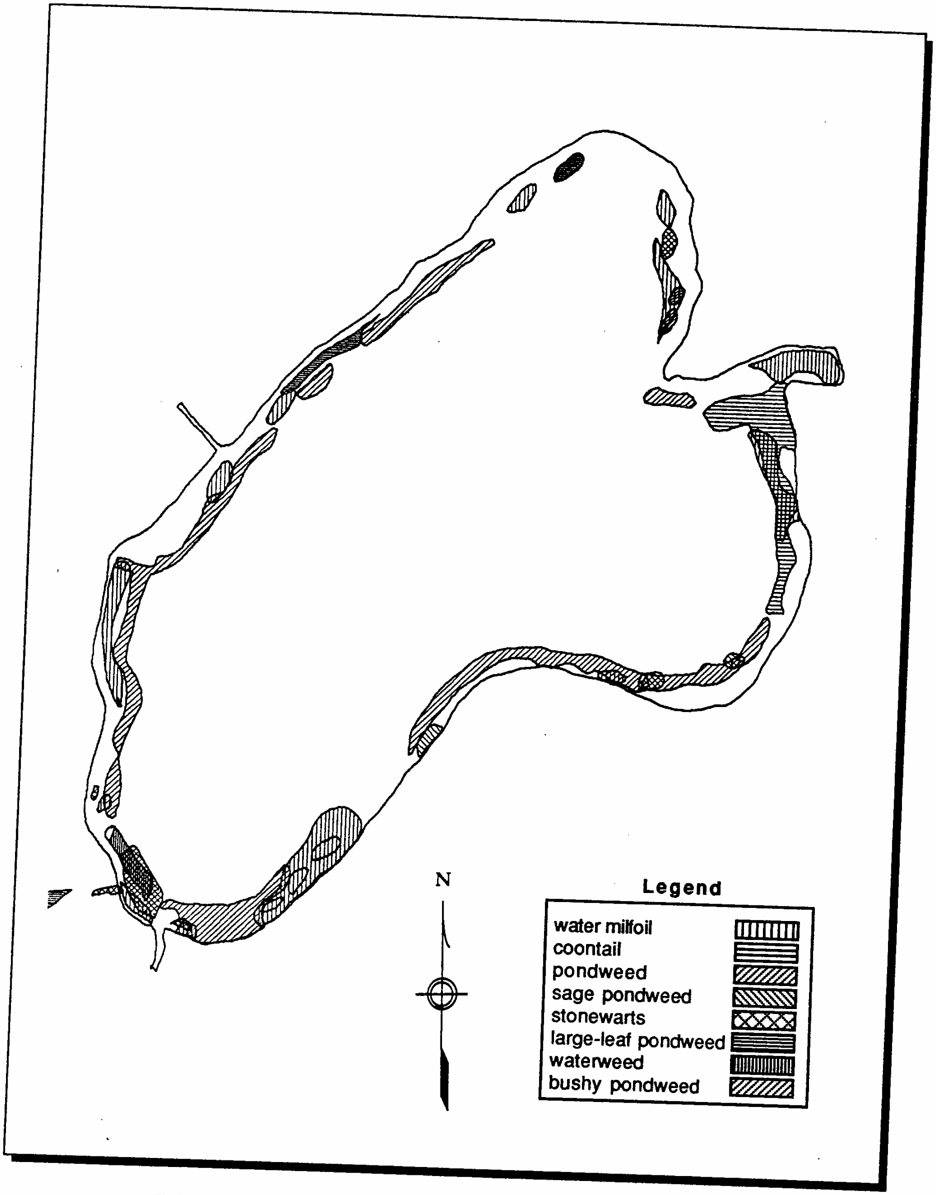


FIGURE 3-7b. Submergent macrophyte distribution in Fish Lake.

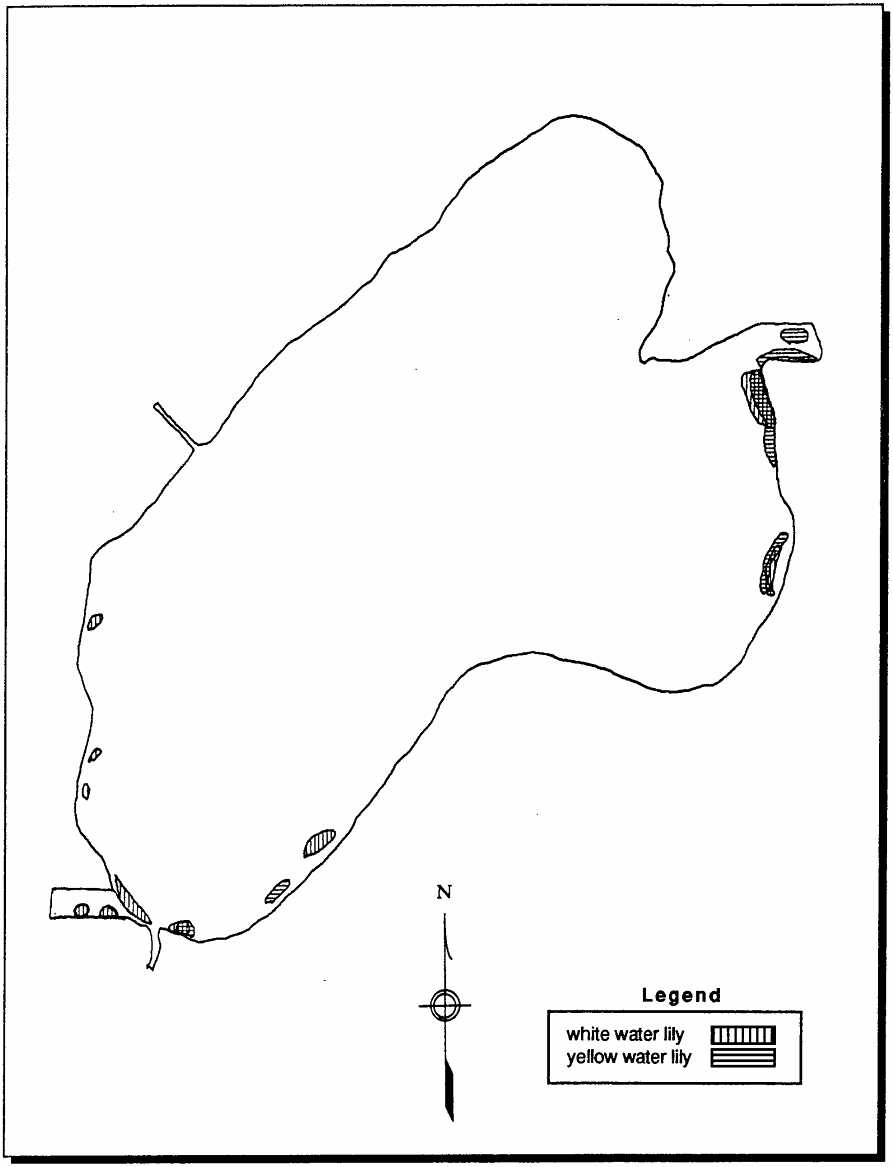


FIGURE 3-7c. Floating macrophyte distribution in Fish Lake.

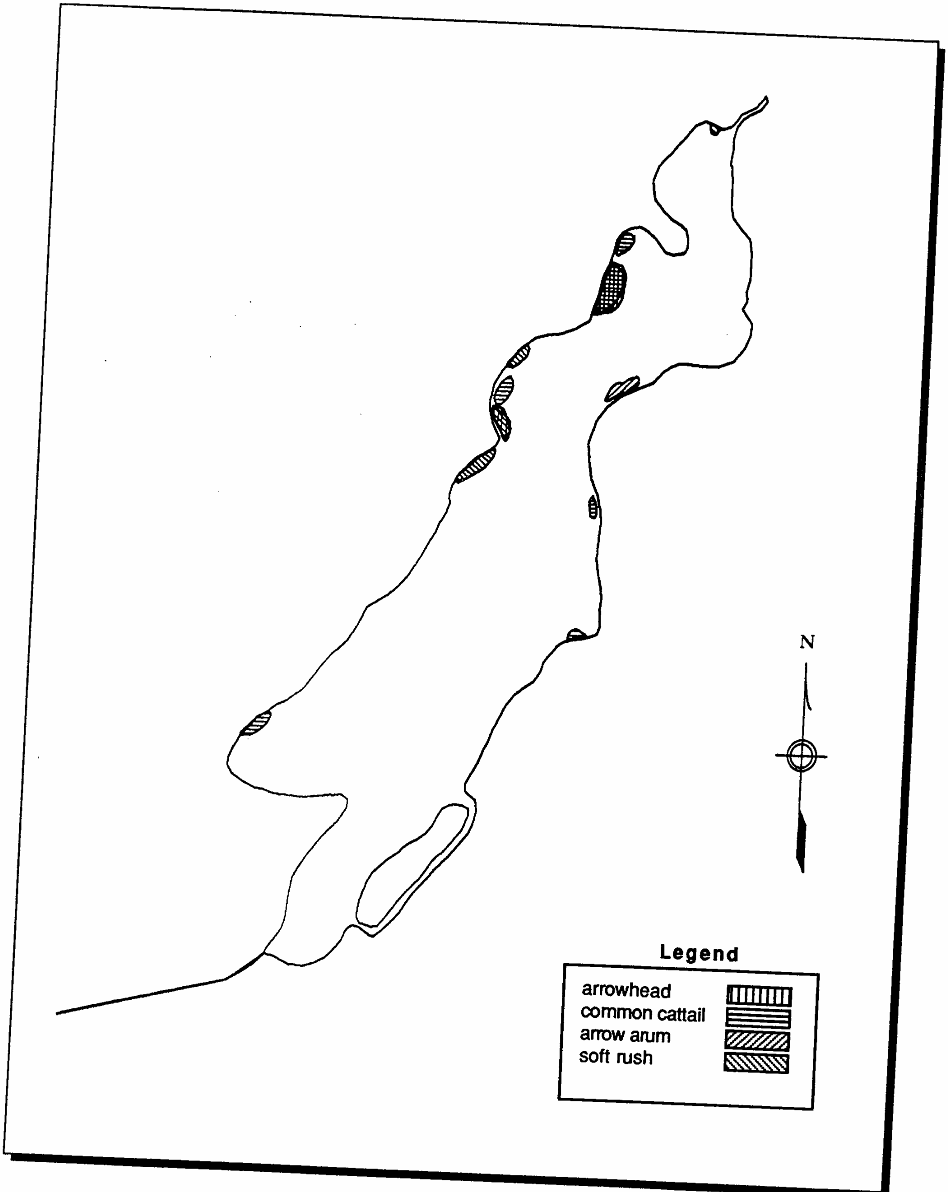


FIGURE 3-8a. Emergent macrophyte distribution in Royer Lake.

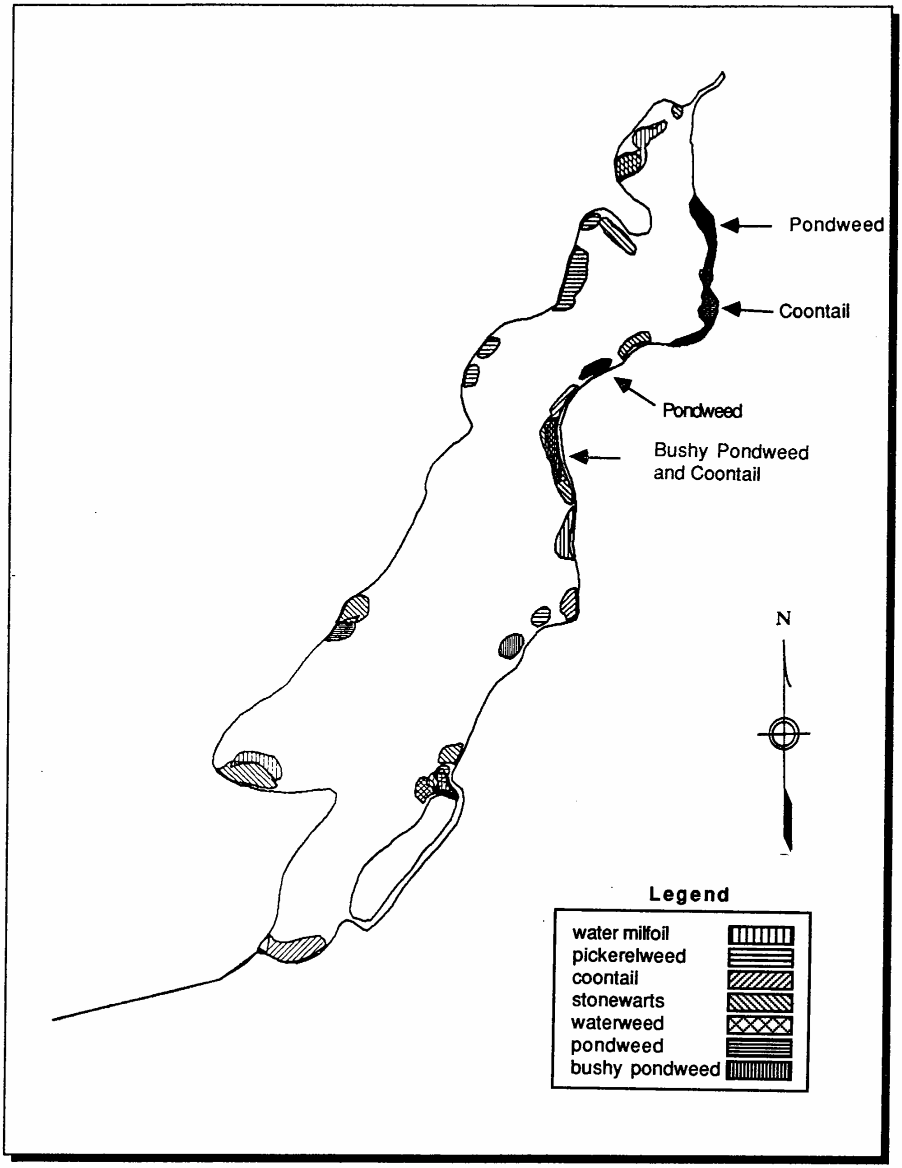


FIGURE 3-8b. Submergent macrophyte distribution in Royer Lake.

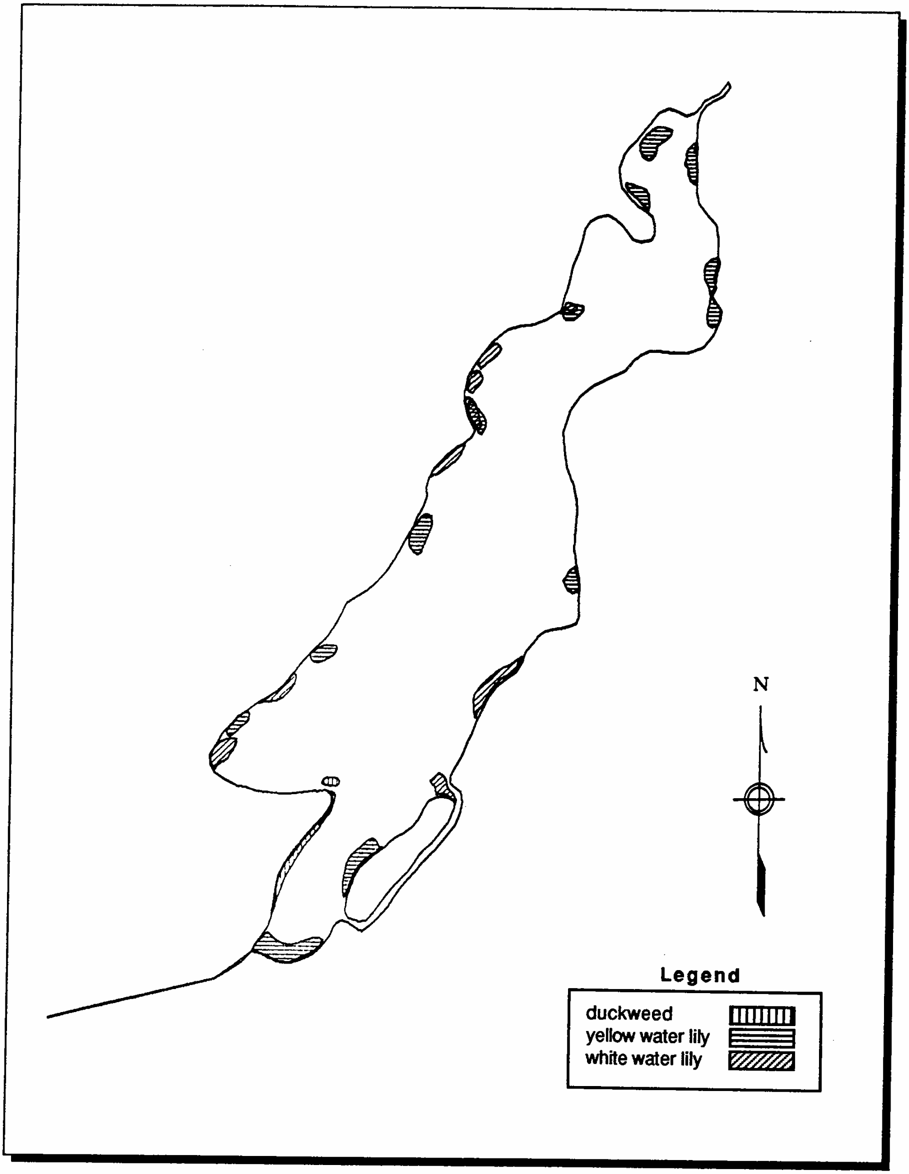


FIGURE 3-8c. Floating macrophyte distribution in Royer Lake.

TABLE 3-16. **List of macrophyte species found in Fish Lake on September 28, 1989.**

COMMON NAME	SCIENTIFIC NAME	HABITAT CLASS
yellow water lily	*Nuphar advena*	Floating
white water lily	*Nymphaea ordorata*	Floating
soft rush	*Juncus effusus*	Emergent
arrow arum	*Peltandra virginica*	Emergent
pickerelweed	*Pontedria cordata*	Emergent
common cattail	*Typha latifolia*	Emergent
coontail	*Cerataphyllum demersum*	Submergent
stonewarts	*Chara sp.*	Submergent
bushy pondweed	*Najas flexilis*	Submergent
waterweed	*Elodea canadensis*	Submergent
water milfoil	*Myriophyllum spicatum*	Submergent
large-leaf pondweed	*Potamogeton amplifolius*	Submergent
pondweed	*Potamogeton augustifolius*	Submergent
sago pondweed	*Potamogeton pectinatus*	Submergent

3.2.6 Trophic State Assessment

The calculations used to derive the BonHomme EI values for this study are presented in Tables 3-18 and 3-19. The index used for this calculation is not directly comparable to that documented by IDEM (1986). The index has recently been revised by IDEM staff. The phytoplankton range has been adjusted and now reflects the number of organisms present per liter of lake water sampled (IDNR, 1990). The revised EI values were calculated to be 47 and 50 points for Fish Lake and Royer Lake, respectively. There is one source of uncertainty in this EI calculation which should be noted. The phytoplankton sample from the thermocline was collected in a manner inconsistent with the technique now used by H. BonHomme. A vertical tow from the thermocline to the surface was made instead of a closed 5 foot sample beginning at a depth that includes the thermocline. Based on the recommendations of Kelly Boatman (pers. comm., IDNR), the phytoplankton count data collected from the thermocline was used in the revised EI calculations.

TABLE 3-17. List of macrophyte species found in Royer Lake during the summer of 1989.

COMMON NAME	SCIENTIFIC NAME	HABITAT CLASS
duckweed	*Lemna minor*	Floating
yellow water lily	*Nuphar advena*	Floating
white water lily	*Nymphaea ordorata*	Floating
soft rush	*Juncus effusus*	Emergent
arrow arum	*Peltandra virginica*	Emergent
pickeralweed	*Pontederia cordata*	Emergent
arrowhead	*Sagittaria* sp.	Emergent
common cattail	*Typha latifolia*	Emergent
coontail	*Cerataphyllum demersum*	Submergent
stonewarts	*Chara* sp.	Submergent
waterweed	*Elodea canadensis*	Submergent
water milfoil	*Myrophyllum spicatum*	Submergent
bushy pondweed	*Najas flexilis*	Submergent
pickerelweed	*Pontederia cordata*	Submergent
pondweed	*Pontamogeton augustifolius*	Submergent
pondweed	*Potamogeton Spirillus*	Submergent

Both water bodies are placed in the "Class Two" category within the IDEM Lake Management scheme. Lakes in this category are described as "productive and slowly moving toward senescence." They often support extensive concentrations of macrophytes and/or algae but not at levels that severely impair beneficial uses (e.g., fishing, swimming). Most Indiana lakes fall into this category. It should be noted that the EI values are equivalent in both lakes to the previous values revised by BonHomme (i.e., 42 and 45).

Calculations of the Carlson TSI for Fish and Royer Lakes were based on the Chl a and TP concentrations in the surface waters as well as the Secchi disk transparency of each lake. The results of these calculations are presented in Table 3-20. The range of TSI numbers was between 46 and 54 for Fish Lake, and 39 and 52 for Royer Lake. TSI numbers of 50 to 60 are characteristic of the lower boundary of classical eutrophy. Lakes with TSI numbers in this range are characterized by decreased water transparency, increased macrophyte growth, and anoxic hypoliminia during the summer months. TSI values of 40 to 50 are indicative of mesotrophic waters. Lakes in this category have moderately clear water, but have increased probability of anoxia during the summer (Carlson, 1979).

A comparison of TSI values for Fish Lake shows that the Secchi disk and TP based values are nearly equivalent, while the Chl a based value was marginally lower. This finding indicates that non-algal particulates or color dominated light attenuation at the time of sampling (Carlson, 1983). TSI values calculated for Royer Lake indicate that the Secchi disk and Chl a based values were equal and that the

TABLE 3-18. **Eutrophication index calculations performed on data collected from Fish Lake on 24 August 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Total Phosphorus (mg/l)			
Less than 0.03	0	X	0
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4		0
Greater than 0.99	5		0
Soluble Phosphorus (mg/l)			
Less than 0.03	0	X	0
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4		0
1.0 or more	5		0
Organic Nitrogen (mg/l)			
At least 0.50	1		0
0.60 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/l)			
At least 0.3	1		0
0.40 to 0.80	2		0
0.90 to 1.90	3		0
2.0 or more	4	X	4
Ammonia (mg/l)			
Less than 0.30	0	X	0
At least 0.30	1		0
0.40 to 0.50	2		0
0.60 to 0.90	3		0
1.0 or more	4		0
Percent oxygen saturation at 5 feet			
114% or less	0		0
115% to 119%	1		0
120% to 129%	2	X	2
130% to 149%	3		0
150% or more	4		0

TABLE 3-18 (continued). **Eutrophication index calculations performed on data collected from Fish Lake on 24 August 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Percent of Water Column with at least 0.1 ppm DO			
28% or less	4		0
29% to 49%	3		0
50% to 65%	2		0
66% to 75%	1		0
76% to 100%	0	X	0
Secchi Disk Transparency			
5 feet or less	6	X	6
greater than 5 feet	0		0
Light Transmission at 3 Feet			
0% to 30%	4		0
31% to 50%	3	X	3
51% to 70%	2		0
71% or greater	1		0
Total Plankton from 5 foot Tow (#/l)			
Less than 4700/l	0		0
4701/l to 9500/l	1		0
9501/l to 19000/l	2		0
19001/l to 28000/l	3		0
28001/l to 57000/l	4		0
57001/l to 95000/l	5		0
95001/l or more	10	X	10
Blue-green dominance	5 additional points		5
Total Plankton from 5 foot Thermocline Tow (#/l)			
Less than 9500/l	0		0
9501/l to 19000/l	1		0
19001/l to 47000/l	2		0
47001/l to 95000/l	3		0
950001/l to 190000/l	4		0
190001/l to 285000/l	5		0
285001/l or more	10	X	10
Blue-green dominance	5 additional points		5
Populations of 950000 or more	5 additional points		0

INDEX VALUE			47

TABLE 3-19. **Eutrophication index calculations performed on data collected from Royer Lake on 24 August 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Total Phosphorus (mg/l)			
Less than 0.03	0		0
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
Greater than 0.99	5		0
Soluble Phosphorus (mg/l)			
Less than 0.03	0		0
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
1.0 or more	5		0
Organic Nitrogen (mg/l)			
Less than 0.50	0		0
At least 0.50	1		0
0.60 to 0.80	2		0
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/l)			
At least 0.3	1		0
0.40 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Ammonia (mg/l)			
At least 0.30	1		0
0.40 to 0.50	2		0
0.60 to 0.90	3		0
1.0 or more	4	X	4
Percent oxygen saturation at 5 feet			
114% or less	0		0
115% to 119%	1		0
120% to 129%	2	X	2
130% to 149%	3		0
150% or more	4		0

TABLE 3-19 (continued). **Eutrophication index calculations performed on data collected from Royer Lake on 24 August 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Percent of Water Column with at least 0.1 ppm DO			
28% or less	4		0
29% to 49%	3	X	3
50% to 65%	2		0
66% to 75%	1		0
76% to 100%	0		0
Secchi Disk Transparency			
5 feet or less	6		0
greater than 5 feet	0	X	0
Light Transmission at 3 Feet			
0% to 30%	4		0
31% to 50%	3	X	3
51% to 70%	2		0
71% or greater	1		0
Total Plankton from 5 foot Tow (#/l)			
Less than 4700/l	0		0
4701/l to 9500/l	1		0
9501/l to 19000/l	2		0
19001/l to 28000/l	3		0
28001/l to 57000/l	4		0
57001/l to 95000/l	5		0
95001/l or more	10	X	10
Blue-green dominance	5 additional points	X	5
Total Plankton from 5 foot Thermocline Tow (#/ml)			
Less than 9500/ml	0		0
9501/l to 19000/l	1		0
19001/l to 47000/l	2		0
47001/l to 95000/l	3		0
95001/l to 190000/l	4		0
190001/l to 285000/l	5		0
285001/l or more	10	X	10
Blue-green dominance	5 additional points		5
Populations of 950000 or more	5 additional points		0

INDEX VALUE			50

TABLE 3-20. **Carlson Trophic State Index values for Fish and Royer Lakes (data from 24 August 1989).**

	Secchi Disk (m)	TSI (SD)	Chl a (mg/m^3)	TSI (Chl)	TP (mg/m^3)	TSI (TP)
Fish Lake	1.5	54	4.81	46	27.0	52
Royer Lake	1.8	52	8.54	52	11.0	39

TP based value was lower. According to Carlson (1983), this finding suggests that phosphorus limits algal production.

3.3 WATERSHED SURVEY RESULTS

The findings of the watershed survey are presented in this section. Topics addressed include climate, hydrology, soils, and land use. It is critical to understand these characteristics because they influence the dynamics of water, sediment, and nutrients associated with the lake. The results of the AGNPS modeling exercise are also addressed because this model was an important tool for integrating the effects of these factors and interpreting their significance.

3.3.1 Climate

Climate is often considered a "master variable" in controlling the condition of inland water bodies. It drives the hydrologic cycle, directly governing hydrologic inputs such as rainfall and outputs such as evaporation. It affects soil moisture conditions and plant growth which in turn influence the potential for surface water losses through evapotranspiration and infiltration. Runoff and stream flow are also dependent on the weather. Factors to consider when analyzing climate include:

- Type of precipitation
- Timing of precipitation
- Duration of precipitation
- Direction of storm movement
- Temperature
- Solar energy input.

Selected monthly climatic data for the Fish and Royer Lake region are listed in Table 3-21. Discussion of the weather characteristics for the area is presented below. Information for this report was produced using data from a computerized weather generator (Nick and Lane, 1988), the Soil Conservation Service (USDA, 1977), and the Weather Atlas of the United States (DOC, 1968).

The climate of LaGrange County, influenced both by cool Canadian air masses from the north and by humid, semitropical air masses from the south, can be generally described as continental, although there

TABLE 3-21. Selected climatic data for the Fish and Royer Lake watershed.

Month	Precip (In)	Precip Duration (Hour)	Max Temp (°F)	Min Temp (°F)	Solar Radiation (Ly/Day)
January	2.47	17.6	33.3	17.3	123.6
February	2.55	16.3	35.4	18.4	195.7
March	2.79	20.8	45.4	26.5	293.2
April	4.03	22.0	58.0	37.0	372.2
May	3.75	17.8	69.9	47.9	467.6
June	3.29	12.0	79.4	58.3	528.3
July	3.61	15.5	84.2	62.6	520.2
August	2.68	13.9	82.0	59.6	467.1
September	2.46	14.5	75.0	53.6	384.2
October	3.24	14.1	63.5	42.9	271.3
November	2.93	16.2	46.8	30.1	157.7
December	1.99	18.0	35.5	20.4	111.1
AVERAGE	2.98	16.6	59.0	39.6	324.4
TOTAL	35.79	198.6			

is modification from the Great Lakes. The average winter temperature is 27^{o} F (-2.8^{o} C) with an average daily minimum temperature of 20^{o} F (-6.7^{o} C). The average summer temperature is 71^{o} F (21.7^{o} C) with an average daily maximum temperature of 82^{o} F (27.8^{o} C). The average relative humidity in mid-afternoon is near 65%. On most nights, however, relative humidity increases to an average at dawn of around 80%. Dew and frosts are common.

Solar radiation ranges between an average minimum of 111 Langleys per day in December and a maximum of 528 Langleys per day in June. The annual mean is 324 Langleys per day. The sun is observed for 58% of the daylight hours, including approximately 37% in December and 72% in July. An average of 77 days are completely clear each year, and 181 days are overcast. The remainder are either partly sunny or partly cloudy.

Precipitation is evenly distributed throughout the year (Figure 3-9), with a monthly average rainfall of 2.98 inches (7.57 cm). Spring and early summer rains generally exceed precipitation levels during the rest of the year and are considered reliable for ensuring excellent crop growing conditions. Average duration of storms is approximately 16.6 hours, with a minimum of 12.0 hours in June and a maximum of 22.0 hours in April. The mean annual precipitation is 35.8 inches (90.9 cm). Annual snowfall averages 33.0 inches (83.82 cm).

Winds are generally out of the south-southwest at 8 miles per hour in summer, and out of the northwest at 12 miles per hour in winter. Therefore, summer storms traverse the Fish and Royer Lake watershed

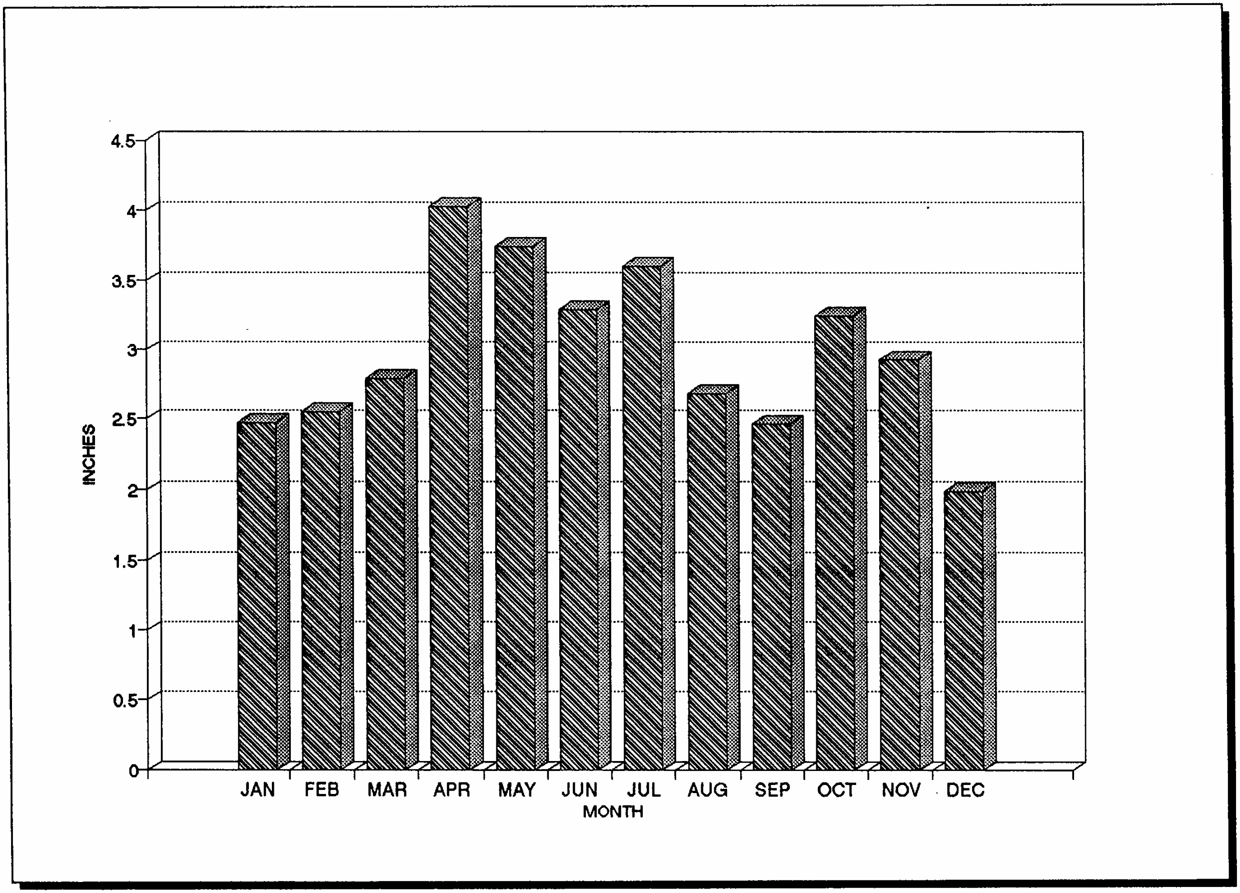


FIGURE 3-9. Monthly distribution of precipitation in the Fish & Royer Lake watershed.

from southwest to northeast and runoff concentrates first from the southwestern sections of the catchment. Winter storms travel from northwest to southeast but often bring snow rather than rain and, thus, runoff concentration is less of an issue. The only damaging winds arise from thunderstorms or tornadoes, although tornadoes are quite rare. Thunder storms occur about 45 days of the year.

Investigation of precipitation chemistry in this study focused on plant nutrients (i.e., nitrogen and phosphorus) in an attempt to quantify atmospheric loading of these elements. Although information on the subject was scarce, data were found for two monitoring stations within a reasonable distance of Fish and Royer Lakes: Benton Harbor, Michigan and Put-in Bay, Ohio. Interpolated averages were found for total phosphorus (0.07 mg/l), nitrate (0.45 mg/l), and ammonia (1.18 mg/l). Data were unreliable for total nitrogen. Combining these averages with annual atmospheric water loading yielded estimates for atmospheric nutrient loading. Annual atmospheric loading for Fish Lake was calculated to be 56.9 pounds/year (25.8 kg/yr) of total phosphorus, 365.1 pounds/year (165.6 kg/yr) of nitrate-nitrogen, and 957.6 pounds/year (434.3 kg/yr) of ammonia-nitrogen. Royer Lake receives 39.2 pounds/year (17.8 kg/yr) of total phosphorus, 252.0 pounds/year (114.3 kg/yr) of nitrate-nitrogen, and 660.8 pounds/year (299.7 kg/yr) of ammonia-nitrogen.

It should be noted, however, that although these figures formed the basis for assessing atmospheric nutrient loading, the supporting data were gathered at considerable distances from either Fish or Royer Lakes and a large degree of uncertainty accompanies them. In particular, phosphorus concentrations in rainfall may be considerably higher in LaGrange County than indicated by these figures. Intensive row crop agriculture is practiced in many areas of the County and tends to contribute large amounts of particle-bound phosphorus to the atmosphere in the form of dust. Such areas generally experience increased phosphorus levels in precipitation.

3.3.2 Hydrology

Another "master variable" controlling the condition of water bodies is the physical layout of the drainage basin. The general topographic attributes of the catchment area influence the behavior of water once it reaches the ground. In conjunction with climate, hydrologic features affect runoff volume (i.e, mass input), velocity (i.e., erosional capacity), and timing (i.e., flood potential). Important aspects of a watershed investigation include consideration of the following features:

- Basin area
- Catchment shape
- Slope
- Geographic orientation
- Drainage pattern

Characterization of hydrologic features for this study focused on two types of analyses: (1) a general description of watershed morphological attributes, and (2) calculation of an approximate mass-balance water budget. Appropriate discussion of the components of each analysis are included.

The Fish and Royer Lake watershed covers approximately 6312 acres (2555 ha) and is irregularly shaped (Figure 3-10). Its longitudinal axis runs from southwest to northeast. Its gravitational center is situated 1.7 miles (2.7 km) southeast of the Fish Lake outlet. The perimeter of the watershed is approximately 18.4 miles (29.6 km). The most distant point of the basin lies at its eastern tip, close to the intersection of the 900 East Road and the 200 South Road. This point is approximately 4.3 miles (7.0 km) from the lake outlet and constitutes the endpoint of the watershed's "axial length." The average width of the basin, defined as the ratio of catchment area to axial length, is 2.8 miles (4.6 km). These and other key morphological parameters are presented in Table 3-22. Discussion of the significance of pertinent indices follows.

TABLE 3-22. Morphological features of the Fish and Royer Lake watershed.

ATTRIBUTE	TRADITIONAL VALUE	METRIC VALUE
Area	6,312 acres	2,555 ha
Perimeter	18.4 miles	29.6 km
Axial Length	3.4 miles	5.5 km
Average Width	2.8 miles	4.6 km
Average Slope	3.6 %	same
Minimum Slope	0.0	same
Maximum Slope	11.49 %	same
Form Factor	0.83 (unitless)	same
Compactness Coeff.	1.66 (unitless)	same
Eccentricity	0.87 (unitless)	same
Drainage Density	1.56 miles/mile^2	2.51 km/km^2

The slope of a drainage basin has an important and complex role influencing infiltration, runoff, soil moisture, and groundwater contribution to stream flow. Slope is one of the major factors governing the time required by overland flow to reach channels where it is quickly transferred downstream (i.e, time of concentration). Greater slopes generally increase runoff velocity, thereby decreasing time of concentration. Elevated runoff velocity is also accompanied by diminished infiltration and enhanced erosional capacity. The Fish and Royer Lake watershed has an average slope 3.6%, reflecting the relatively flat topography of the region. The maximum slope, 11.5%, occurs in a hilly region southwest of the intersection 200 South Road and 600 East Road. The elevation of the basin ranges from 935 feet (285 m) near the lakes to 1044 feet (318 m) at the eastern extension of the watershed.

Basin orientation, often called "aspect", refers to the compass direction toward which most of the slopes in the catchment face. Since Royer Lake is situated west of its drainage area, most slopes face west. Likewise, because Fish Lake is situated in the northwestern portion of the watershed, most slopes in its catchment basin face north-northwest. This orientation is important, especially in winter, because snow on these slopes is not exposed to the most direct angle of solar incidence and, therefore, does not melt as quickly. Snow cover tends to build up in these areas, storing a considerable amount of moisture until

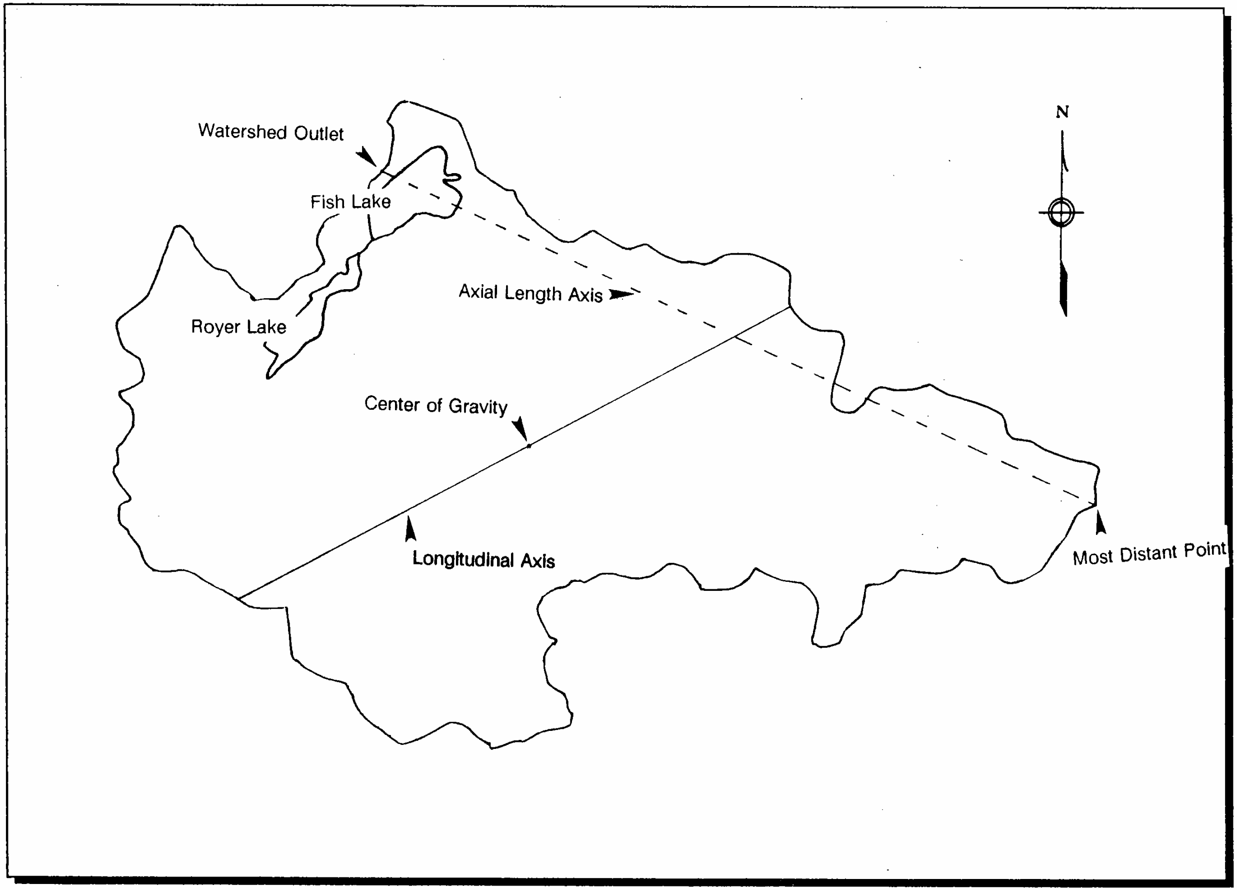


FIGURE 3-10. Outline and morphological features of the Fish & Royer Lake watershed.

early spring thaws. When snow melt does occur, the stored water is released, emulating the effects of a large rainfall event developing over a relatively short time. Higher stream flows can be expected in the early spring.

The shape of a drainage basin governs the rate at which runoff is supplied to the catchment's main water body following a precipitation event. Although it is difficult to adequately express shapes by using numerical indices, three such measures were calculated for the Fish and Royer Lake watershed: (1) form factor, (2) compactness coefficient, and (3) eccentricity. Being the ratio of average width to axial length, the form factor is an indicator of the relative elongation of the catchment. Basins with form factors that approach 1.0 are said to be uniform and non-elongated. This type of watershed is more likely to have intense or lengthy rainfall over its entire extent. The resulting runoff tends to reach streams and lakes from all points in the basin simultaneously and, therefore, watersheds with form factors near 1.0 are usually considered prone to high flood peaks. The Fish and Royer Lake watershed has a form factor of 0.83 and, using this criteria alone, normally would be classified as non-elongated and likely to experience high flood peaks.

The second shape index estimated for the Fish and Royer Lake basin was the compactness coefficient (CC). The CC is a test for uniform shape that compares the perimeter of the watershed with the perimeter of a circle of equal area. Catchments with CC values that approach 1.0 are nearly circular while those with CC values that diverge from 1.0 are more complex. Being uniform, circular watersheds tend to contribute runoff simultaneously and, thus, are also prone to elevated flood peaks resulting from intense or lengthy rainfall events. The Fish and Royer Lake catchment has a CC value of 1.66, indicating a somewhat non-circular shape. A result of 1.66 does not represent a major departure from uniformity, however, and the watershed may be expected to sustain elevated flood peaks.

The third shape index used in this study was watershed eccentricity, a measure relating watershed shape to that of an ellipse. Again, the premise behind the eccentricity calculation is that flood peaks are higher in more rounded catchments rather than in more elongated ones. Eccentricity values that approach 0.0 indicate a rounded shape and, thus, are usually associated with high flood peaks. Conversely, values that approach infinity are associated with low flood peaks. In empirical studies of uniform storms covering an entire watershed, this index has been found to be more accurate than either the form factor or the compactness coefficient. The Fish and Royer Lake basin has an eccentricity value of 0.87, indicating moderately high flood peak potential.

Another important characteristic of any watershed is the arrangement of the streams that drain it. The efficiency of the drainage system and, therefore, the characteristics of flood peaks are directly dependent on this attribute. Generally, if a basin is well-drained and the length of overland flow is short, surface runoff concentrates rapidly and contributes to a high flood peak. Average flows are usually low in such systems. One measure of drainage efficiency used in this study is "drainage density." Being the ratio of total length of perennial channels to total watershed area, this index provides an indication of basin stream coverage. The Fish and Royer Lake watershed has a drainage density of 1.56 miles/square mile (2.51 km/km^2) and, using this criteria alone, would be considered well-drained and prone to flash flood flows. This tendency is mitigated somewhat by long overland flow (not computed) and deep, infiltratable soils (Section 3.2.3). The pattern of the drainage network can be described as dendritic.

An annual water budget was computed separately for the Fish Lake and Royer Lake watershed using the climatic and hydrologic data discussed above. Water budget components included information on inputs (e.g., direct rainfall, runoff, and springs) and outputs (e.g., evaporation, overflow, and leakage). These components are summarized in Tables 3-23 and 3-24. The total calculated volume of water input to Fish Lake was 3.55 X 10^8 ft^3 (1.01 X 10^7 m^3). Of this amount, 54.1% was attributed to runoff from the catchment (including stream flow), 42.3% was attributed to outflow from Royer Lake, and 3.6% was attributed to direct rainfall on the lake surface. Of the outputs, lake overflow constituted 90.9% of the total, while evaporation accounted for 9.1%. Hydraulic retention time, the ratio of lake volume to inflow volume, was estimated to be 0.47 years, indicating that Fish Lake experiences a fairly rapid turnover of its volume. Retention times of less than 1 year are fairly common for lakes in the northeastern part of Indiana. The total calculated volume of water input to Royer Lake was 1.89 X 10^8 ft^3 (5.35 X 10^6 m^3). Of this amount, 95.2% was attributed to runoff from the catchment (including stream flow) and 4.8% was attributed to direct rainfall on the lake surface. Of the outputs, lake overflow constituted 96.5% of the total, while evaporation accounted for 3.5%. Hydraulic retention time, the ratio of lake volume to inflow volume, was estimated to be 0.32 years, indicating a rapid turnover of water also occurs in Royer Lake.

Potential evapotranspiration (PET) is used as a measure of the maximum possible evaporation through the soil and vascular plants. Analysis of PET gives researchers an indication of water losses from the surface flow regime. On a practical level, calculation of this parameter forms the basis of determining local crop suitability, irrigation requirements, and reservoir design needs. An important subtraction of water from a drainage basin, evapotranspiration dominates the water balance and controls many non-surface phenomena including soil moisture content and groundwater recharge.

Potential evapotranspiration in the Fish and Royer Lake watershed was calculated at 34.6 inches (88.0 cm) per year, approximately one inch less than the annual rainfall. Actual evapotranspiration was, of course, much smaller than this estimate, as evidenced by the 16.8 inches (42.7 cm) of annual runoff in the basin. True evapotranspiration, if calculated as a percentage of the residual of rainfall minus runoff (i.e., infiltration), was probably less than 19 inches (48.3 cm) and limited by soil and climatic conditions. For example, in some soils, moisture percolates rapidly to the water table and is incorporated in groundwater below the reach of plants and other evaporative mechanisms. Climate exerts an influence both during rainy and dry periods, where there is alternately too much or too little water to supply the removal process. Though not a direct surrogate for true evapotranspiration, PET indicates the magnitude of potential water losses, given a uniform and non-limited water reserve. The high PET value for the Fish and Royer Lake watershed was not considered unusual.

3.3.3 Soils

The soils in LaGrange County formed from glacial till, glacial outwash, alluvium, and organic material as the area was covered several times during successive ice-ages. Although LaGrange County contains

TABLE 3-23. Components of the Fish Lake water budget.

ANNUALIZED RAW DATA:

ATTRIBUTE	TRADITIONAL VALUE		METRIC VALUE
Watershed Area	3151	acres	269.0 ha
Lake Surface Area	100	acres	23.5 ha
Rainfall	35.8	inches	90.9 cm
Runoff	16.8	inches	42.7 cm
Pan Evaporation (raw)	41.3	inches	104.9 cm
Pan Coefficient	0.77	inches	1.9 cm
Pan Evaporation (adjusted)	31.6	inches	80.3 cm
Potential Evapotranspiration	34.6	inches	88.0 cm

ANNUALIZED WATER BUDGET DATA:

INPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Rainfall	1.30×10^{7} cubic feet	3.68×10^{5} m^3
Runoff	1.92×10^{8} cubic feet	5.44×10^{6} m^3
Groundwater[a]	0.00×10^{1} cubic feet	0.00×10^{1} m^3
Outflow from Royer Lake	1.81×10^{8} cubic feet	5.13×10^{6} m^3
TOTAL INPUTS	3.86×10^{8} cubic feet	1.09×10^{7} m^3

OUTPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Evaporation (adjust)	1.15×10^{7} cubic feet	3.26×10^{5} m^3
Lake Overflow[b]	3.74×10^{8} cubic feet	1.06×10^{7} m^3
Groundwater[a]	0.00 cubic feet	0.00 m^3
TOTAL OUTPUTS	3.86×10^{8} cubic feet	1.09×10^{7} m^3

HYDRAULIC RETENTION DATA:

PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Lake Volume	1.83×10^{8} cubic feet	5.17×10^{6} m^3
Inflow Volume	3.86×10^{8} cubic feet	1.09×10^{7} m^3
Hydraulic Retention	0.47 years	same

[a]Assumed to be 0 due to unavailability of data.

[b]Calculated as the residual of (inputs - evaporation).

TABLE 3-24. Components of the Royer Lake water budget.

ANNUALIZED RAW DATA:

ATTRIBUTE	TRADITIONAL VALUE	METRIC VALUE
Watershed Basin	2952 acres	1195 ha
Lake Surface	69 acres	27.9 ha
Rainfall	35.8 inches	90.9 cm
Runoff	16.8 inches	42.7 cm
Pan Evaporation (raw)	41.3 inches	104.9 cm
Pan Coefficient	0.77 inches	1.9 cm
Pan Evaporation (adjusted)	31.6 inches	80.3 cm
Potential Evapotranspiration	34.6 inches	88.0 cm

ANNUALIZED WATER BUDGET DATA:

INPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Rainfall	8.96×10^{6} cubic feet	2.54×10^{6} m^3
Runoff	1.80×10^{8} cubic feet	5.10×10^{6} m^3
Groundwater[a]	0.00×10^{1} cubic feet	0.00×10^{6} m^3
TOTAL INPUTS	1.89×10^{8} cubic feet	5.35×10^{6} m^3

OUTPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Evaporation (adjust)	7.90×10^{6} cubic feet	2.24×10^{5} m^3
Lake Overflow[b]	1.81×10^{8} cubic feet	5.13×10^{6} m^3
Groundwater[a]	0.00×10^{1} cubic feet	0.00×10^{1} m^3
TOTAL OUTPUTS	1.89×10^{8} cubic feet	5.35×10^{6} m^3

HYDRAULIC RETENTION DATA:

PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Lake Volume	6.01×10^{7} cubic feet	1.70×10^{6} m^3
Inflow Volume	1.89×10^{8} cubic feet	5.35×10^{6} m^3
Hydraulic Retention	0.32 years	same

[a]Assumed to be 0 due to unavailability of data.

[b]Calculated as the residual of (inputs - evaporation).

8 different soil associations (i.e., distinct proportional patterns of soil types), the Fish and Royer Lake watersheds are almost entirely comprised of only two. These associations are:

1. **Wawasee-Hillsdale-Conover association:** These soils are variable within the watershed, ranging from well drained to somewhat poorly drained, and nearly level to strongly sloping. They are moderately coarse textured and medium textured soils found primarily on till plains and moraines. This association is used mostly for crops and pasture. A few areas are in woodland.

2. **Boyer-Oshtemo association:** These soils are well drained and nearly level to moderately steep. They are coarse textured soils found primarily on outwash plains, valley trains, moraines, and kames. Soils in this association are used mainly for cultivated crops or pasture.

It should be noted that grouping soils into associations is helpful only for broad, interpretative purposes. The soils in any one association ordinarily differ in slope, depth, stoniness, drainage, and other characteristics that affect their management.

3.3.4 Land Use

One of the most influential factors governing the longevity and quality of a surface water body is the nature of land use in the drainage basin. Land use categorization within the Fish and Royer Lake watersheds was critical in determining input parameters for the AGNPS model. The sixteen different land use categories and corresponding areal coverages are listed in Table 3-25. A color land use map is presented in Figure 3-11.

The primary land use within the Fish and Royer Lake watersheds was row crop agriculture, accounting for 58% of the total area. Blocks of row crops were dispersed fairly uniformly throughout the watershed, although the area directly southeast of the lakes and the area comprising the eastern quarter of the watershed contained the highest densities of agricultural property. Forested land constituted 22.5% of the watershed and, though present throughout the basin, the majority was located east and south of the lakes in the Grass Lake area. The three residential use categories cumulatively accounted for 3.4% of the area and were distributed with the largest concentrations occurring along the perimeters of Fish and Royer Lakes. Although it comprises a relatively small percentage of the total watershed, the proximity of large population concentrations to the lakes makes their impact a significant one. Increased lawn fertilizer runoff, septic and sewer infiltration, and loss of lake-associated wetlands are characteristic of high density near-shore residential areas.

3.3.5 Modeling Results

Evaluating the Fish and Royer Lake watershed required the digitization of physical features including land use, slopes, streams, and the lakes. The watershed outline, lakes, and streams used in the evaluation are

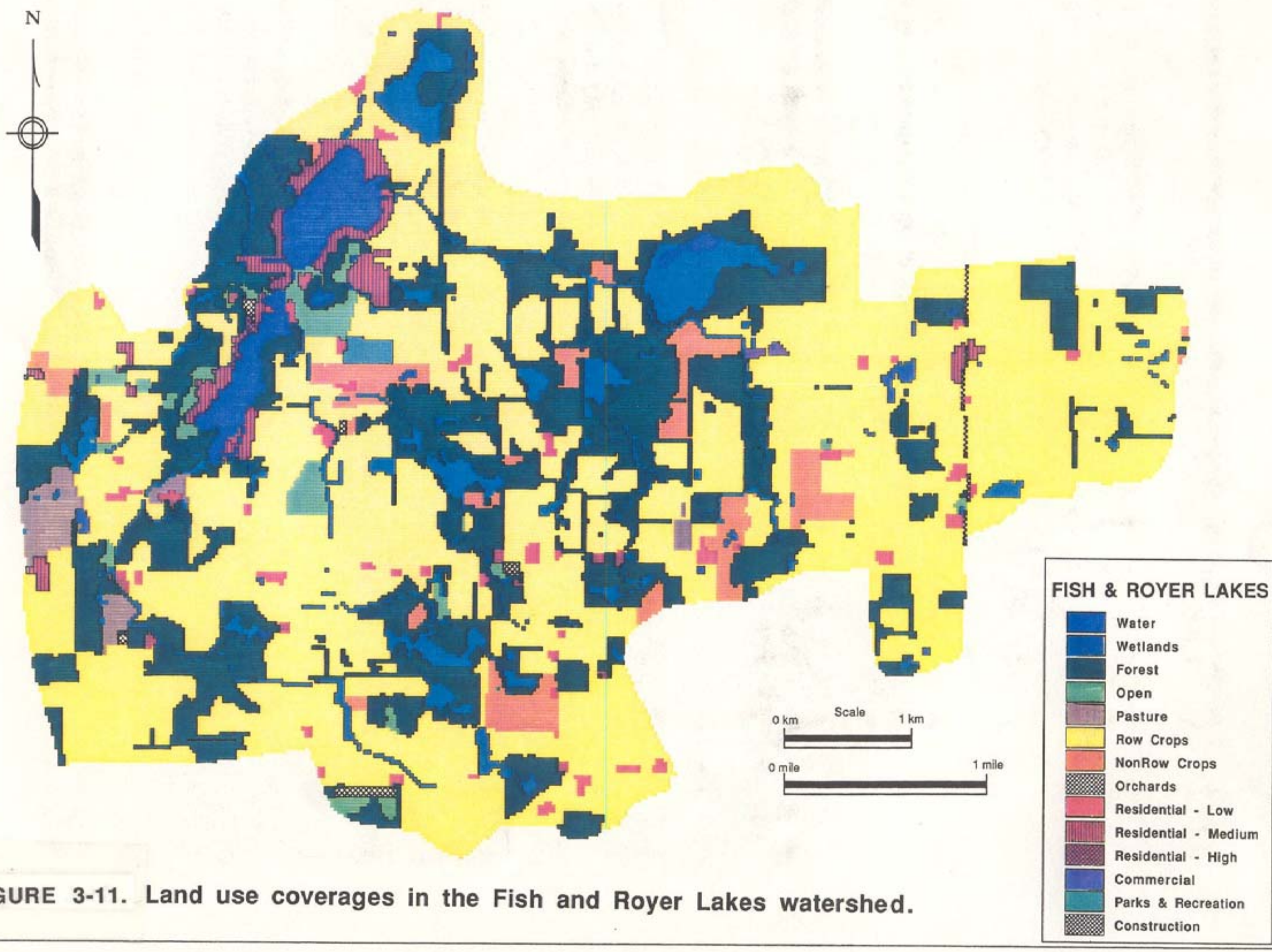


FIGURE 3-11. Land use coverages in the Fish and Royer Lakes watershed.

TABLE 3-25. Land use areas/percentages for the Fish and Royer Lake Watersheds.

WATERSHED CATEGORY	WATERSHED AREA (acre / ha)	PERCENT
Water	198.3 / 80.3	2.57
Wetlands	486.6 / 197.0	6.31
Forest	1735.0 / 702.4	22.49
Open	136.7 / 55.3	1.77
Pasture	90.7 / 36.7	1.18
Row Crops	4474.3 / 1811.5	57.98
Non Row Crops	282.9 / 114.5	3.67
Orchard	12.2 / 4.9	0.16
Feedlot	0.0 / 0.0	0.00
Low Density Residential	114.4 / 46.3	1.48
Medium Density Residential	144.6 / 58.5	1.87
High Density Residential	3.2 / 1.3	0.04
Commercial	4.9 / 2.0	0.06
Parks	16.5 / 6.7	0.21
Excavation	0.0 / 0.0	0.00
Construction	171.7 / 6.5	0.21
TOTALS	7716.4 / 3124.0	100.00

displayed in Figure 3-12. In using the AGNPS model, it was necessary to divide the watershed into a grid of equally sized areas, called "cells" (Figure 3-13). Data characterizing the physical features of the cells were utilized by the model to describe the sediment and nutrient contributions of each cell. This information was used to identify cells exhibiting disproportionate sediment and nutrient export to the lake. Four categories of AGNPS output were evaluated in describing the pertinent export features: (1) sediment yield; (2) cell erosion; (3) nutrient loading; and (4) hydrology. Some of the physical characteristics associated with cells identified by the AGNPS model as "hotspots" for sediment and nutrient production or transport are summarized in Table 3-26.

It is important to note that Royer Lake is directly upstream of Fish Lake and, therefore, is part of Fish Lake's watershed. Royer Lake, by virtue of its location, exerts a marked influence in diminishing sediment and nutrient inputs from the southeastern segment of the watershed to Fish Lake. It was impossible to assess the water quality of Fish Lake without understanding the physical, chemical, and biological conditions in Royer Lake. Sizeable subwatersheds exist for each lake, however, and the areas within these subwatersheds were examined. The following discussion summarizes the AGNPS output from each of the four categories (i.e., sediment yield, cell erosion, nutrient loading, and hydrology).

Sediment Yield and Erosion. Sediment yield from each AGNPS cell is the amount of sediment, in tons, that leaves a cell at its downstream edge. This quantity represents not only the sediment generated inside the cell but also sediment generated in upstream cells. It is important to note that AGNPS also accounts for sediment deposition within a cell if appropriate conditions exist. Therefore, sediment yield is

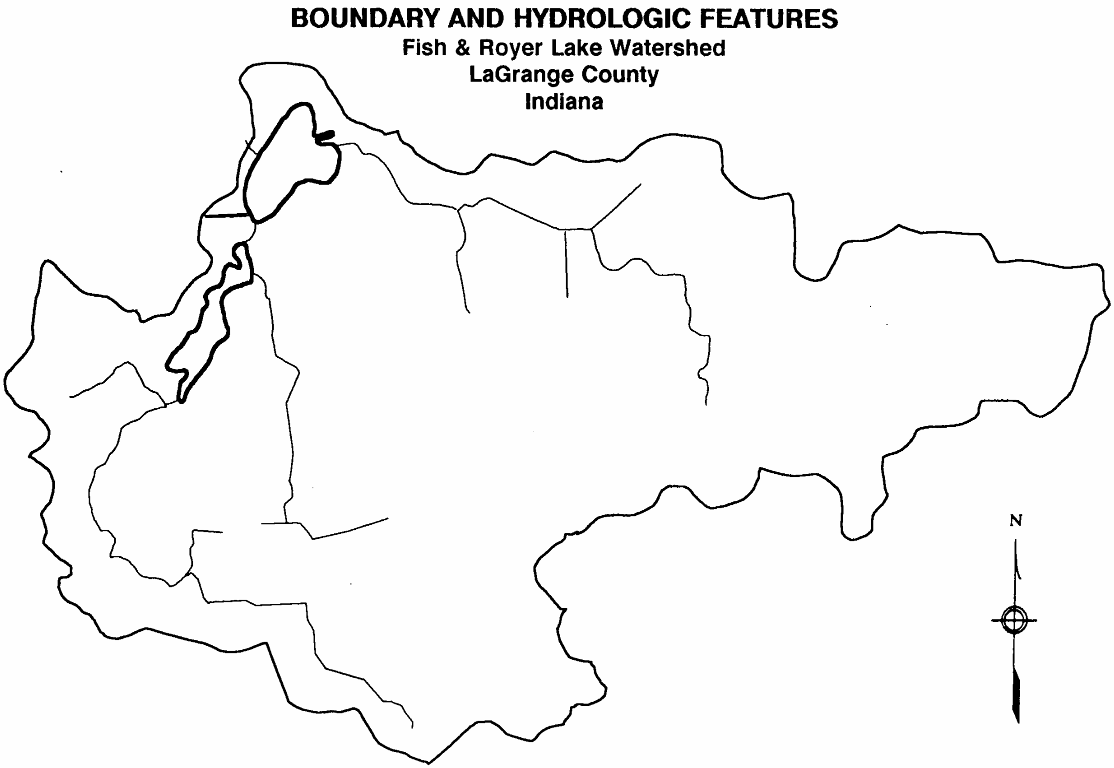


FIGURE 3-12. Digitized Fish & Royer Lake watershed layout used in the AGNPS models.

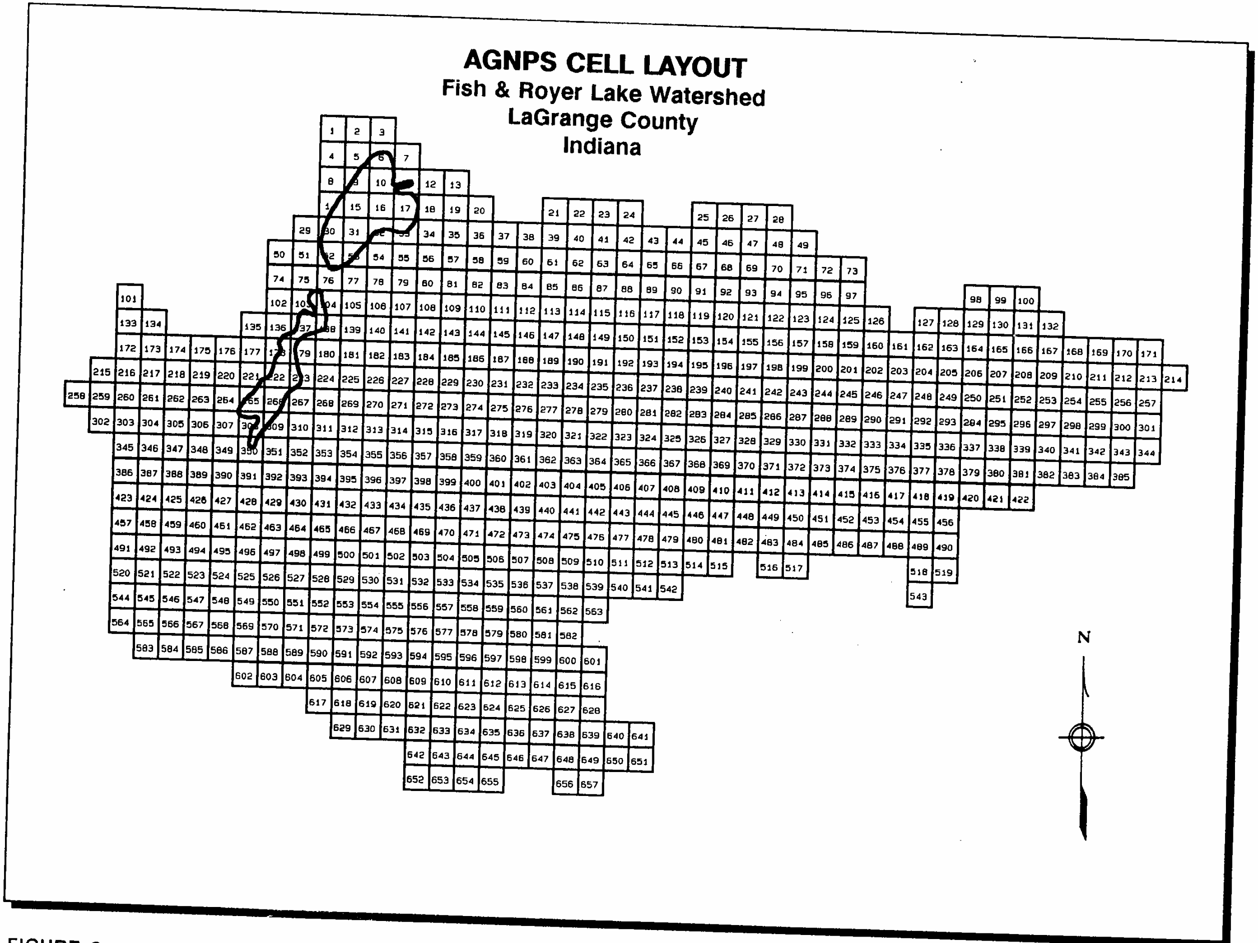


FIGURE 3-13. Layout of Fish & Royer Lake watershed cells used in the AGNPS model.

TABLE 3-26. Summary of physical characteristics of cells determined by the AGNPS model to exhibit high sediment or nutrient export values.

Cell #	Land Slope	Dominant Soil Texture	K-value[1]	Dominant Landuse	Notable Cell Export(s)
3	2.3%	muck/sandy loam	0.01	rowcrops	soluble N-P/runoff
11	0.6%	udorthents	0.00	water/resident.	sediment yield
12	5.0%	fine sand	0.15	rowcrops	sediment yield
18	5.4%	loam	0.24	rowcrops	sediment yield
19	5.4%	sandy loam	0.28	rowcrops	sediment yield
35	4.4%	loamy sand	0.17	rowcrops	sediment yield
36	4.7%	loamy sand	0.17	rowcrops	sediment yield
38	4.0%	loam	0.24	rowcrops	soluble N-P/runoff
58	2.9%	loamy sand	0.17	rowcrops	sediment yield
59	5.4%	loamy sand	0.17	rowcrops	sediment yield
61	4.8%	loam	0.24	woodlands	sediment yield
63	5.3%	loam	0.24	woodlands	sediment yield
83	0.9%	loam	0.24	rowcrops	soluble N-P
101	2.8%	loam	0.28	rowcrops	soluble N-P
138	7.1%	loamy sand/muck	0.17	wetlands	sediment yield
180	4.8%	loamy sand	0.17	rowcrops	sediment yield
223	4.5%	loam	0.24	woodlands	runoff
224	4.7%	loamy sand	0.17	rowcrops	sediment yield
232	8.3%	sandy loam	0.28	rowcrops	cell erosion
275	11.2%	sandy loam	0.28	rowcrops	cell erosion/sediment N-P
292	6.3%	sandy loam	0.28	rowcrops	sediment N-P
293	5.9%	sandy loam/loam	0.28	rowcrops	sediment N-P
311	1.5%	loam	0.28	rowcrops	soluble N-P
335	6.0%	sandy loam	0.28	woodlands	cell erosion
349	8.6%	loamy sand	0.17	woodlands	sediment yield
403	8.1%	sandy loam	0.28	rowcrops	cell erosion
424	6.6%	loamy sand	0.24	rowcrops	sediment yield
514	5.0%	loam	0.28	rowcrops	sediment N-P
600	8.3%	sandy loam	0.28	non-rowcrops	cell erosion/sediment N-P

[1]K-value indicates the susceptibility of a soil to sheet and rill erosion by water.

calculated as the sediment generated in the cell, plus the sediment entering from cells upstream, minus the sediment deposited in the cell.

Cell erosion refers to the amount of sediment that is produced within an individual cell rather than the cumulative amount passing through the cell. It is useful in identifying the cells that experience the greatest amount of internal erosion. The most important factors contributing to high erodibility within a given cell are soil erodibility (i.e., K-factor) and land slope. Land use, water flow velocity, and the presence/absence of defined stream channels within a cell also influence erosion. Areas of intense row-crop agriculture generally produce decidedly higher erosion losses than areas consisting of forests or wetlands. It was necessary to examine cell erosion and sediment yield in order to recognize source areas separately from conduit (i.e., "flow-through") areas. Because management options exist for both source and downstream sediment control, the distinction is often an important one. Results of the model runs are discussed below. Watershed cells with high sediment yield and high cell erosion are displayed in Figures 3-14 and 3-15, respectively.

Fish Lake Sediment Yield: The total sediment yield into Fish Lake was calculated at 170 tons (154 MT). The amount of sediment yield from each cell ranged from no yield to 136 tons (123 MT). The cell with the highest sediment yield, 136.3 tons (123.7 MT), to Fish Lake was cell #58. This cell is located approximately 3300 feet east of the southern shore of Fish Lake between County Roads 100 and 200 South. While the sediment generated within cell #58 was only 5.1 tons (4.6 MT), the amount of sedimententering the cell from upstream sources was significant. The northern quarter of cell #58 is traversed by a stream which originates to the east in Grass Lake. The total area draining towards cell #58 is 3170 acres (1283 ha), nearly 1/2 of the entire watershed. The majority of the drainage area towards this cell is currently used for agricultural purposes.

Other cells located along this stream corridor also exhibited high sediment yields. A total of eleven additional cells were found to contribute greater than 100 tons (91 MT) of sediment. All eleven of them were adjacent to the stream previously mentioned. Cell #59, located directly east of Cell #58, contributed 134 tons (122 MT) of sediment. Cells #35 and #36, situated directly northwest and north of cell #58 respectively, each transported 132 tons (120 MT) of sediment during the simulated storm. Cells #18 and #19, located directly east of Fish Lake south of the stream's mouth, exhibited sediment yields of approximately 132 tons (120 MT). Sediment yields exceeding 120 tons (109 MT) were found in cells #11 and #12, the cells containing the mouth of the stream. Cells #61 and #63 exhibited sediment yields in excess of 100 tons (91 MT). Collectively, these cells constituted the area of highest sediment load to Fish Lake. While the relative sediment contributions of individual cells were not remarkable, the cumulative sediment drainage through this area was significant. It is important to note, however, that the location of these cells within the overall drainage scheme of Fish Lake, rather than their physical characteristics, explains the high sediment yields predicted by AGNPS. Specifically, the modeled sediment yield from these cell was the result of 3 factors:

1) A large sub-basin that channeled runoff through the stream
2) Land uses conducive to sediment export in the sub-basin
3) Moderately erodible soils within the sub-basin.

Royer Lake Sediment Yield: The watershed of Royer Lake is drained by two main tributaries, one of which enters the lake at its northeast corner and one which empties into the lake's southwestern corner. Both of these streams act as conduits of sediment. Loadings from individual cells are less than those in the Fish Lake watershed because sediments are not concentrated in one tributary before entering the lake. The total sediment yield into Royer Lake was calculated at 142 tons (128 MT). The cell with the highest sediment yield to Royer Lake, 57 tons (52 MT), was cell #138. This cell represents an area situated on the northeast side of Royer Lake, west of County Road (CR) 500 East and north of CR 200 South. The eastern third of this cell is traversed by a tributary that originates just south of CR 300 South and enters Royer Lake along its northeastern shore. This stream drains a large, predominantly agricultural area

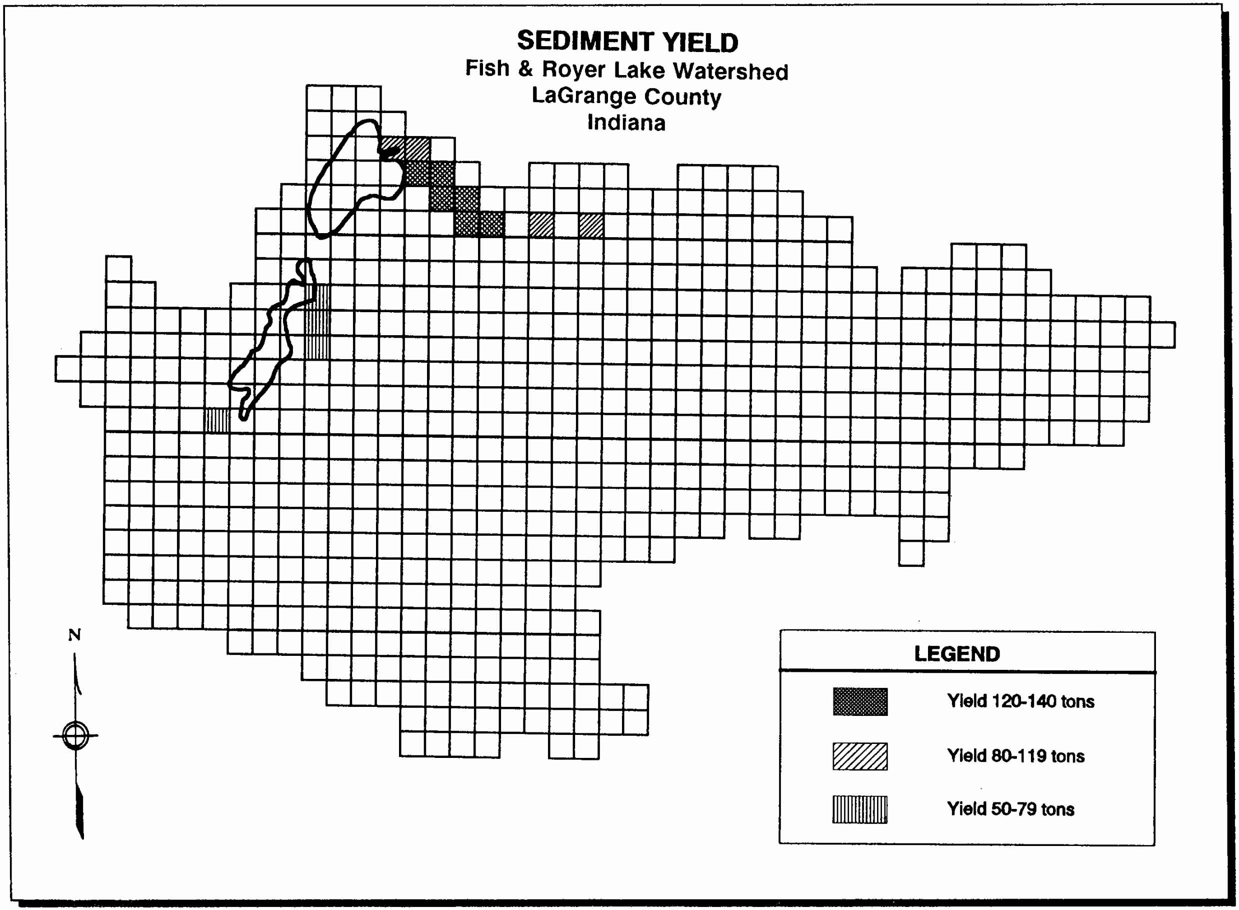


FIGURE 3-14. Modeled sediment yield for the Fish & Royer watershed.

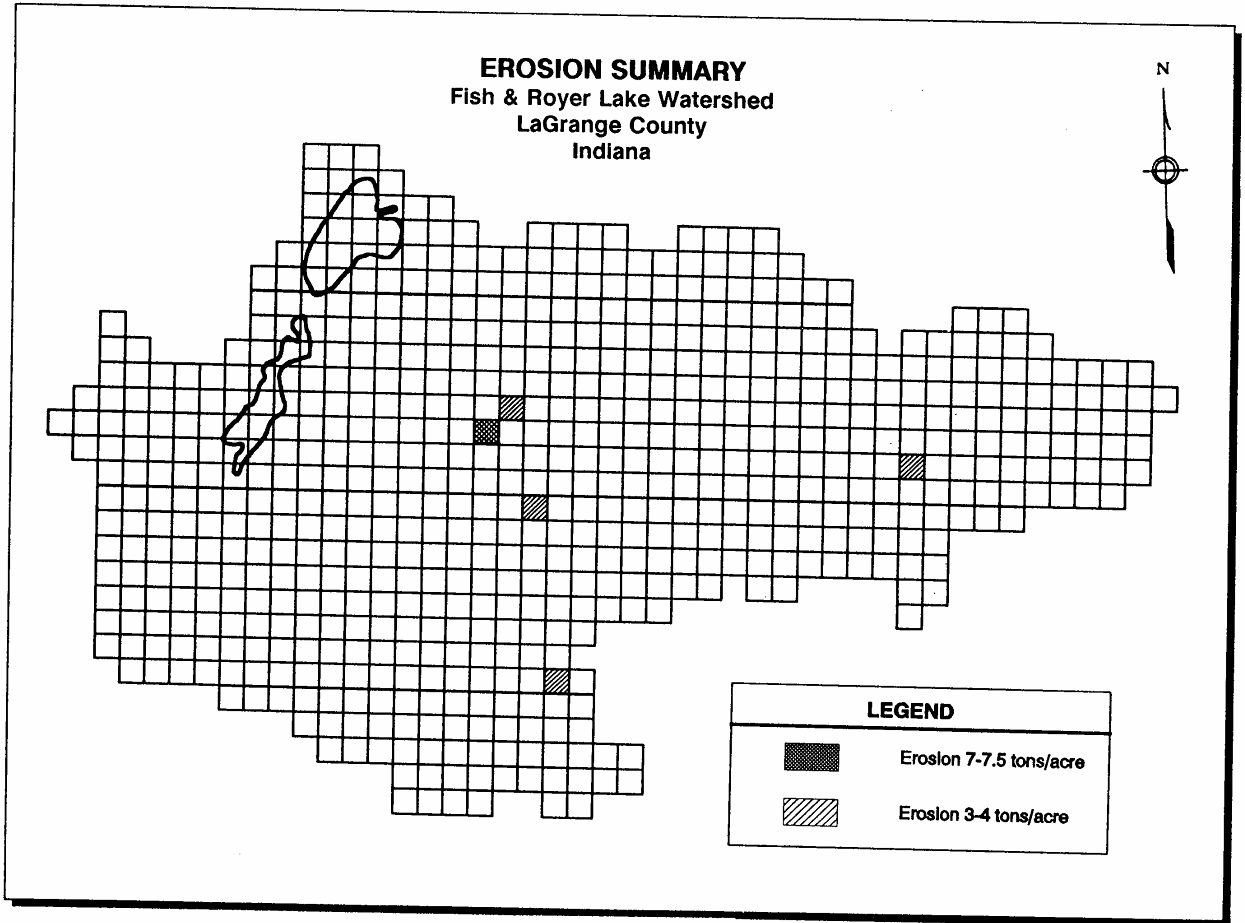


FIGURE 3-15. Modeled cell erosion for the Fish & Royer Lake watershed.

southeast of Royer Lake. The total drainage area of cell #138 is 950 acres (385 ha). The dominant land use within this area is row crop agriculture with a few sizeable pockets of non-row crops and pasture.

The cells directly upstream of Cell #138, Cell #180, and #224, contributed sediment yields in excess of 52 tons (47 MT). With the inclusion of Cell #138, these cells represent the area with the largest sediment export to Royer Lake. As was the case at Fish Lake, the high sediment exports from individual cells are more the result of their physical location within the watershed rather than their specific characteristics.

The tributary of Royer Lake that drains into its southern end was also identified as a significant source of sediments. Cell #349, situated southwest of the southwestern extension of Royer Lake and traversed by the tributary, yielded 52 tons (47 MT) of sediment. Upstream cell #424 also yielded 52 tons (47 MT) of sediment.

Cell Erosion: Cell erosion figures generated by the AGNPS model for the 2-year, 24-hour storm ranged from no sediment production to 7.49 tons/acre (16.79 MT/ha). Cells exhibiting little or no erosion were those areas consisting of water, wetlands, or undrained muck soils. The highest rate of erosion was found in cell #275. This cell is located in the hilly region southwest of the intersection of 200 South Road and 600 East Road. The soil type in this cell was classified as Wawasee fine sandy loam (6-18% slopes). The land use within this area consisted of forested slopes (up to 11.2%) and row crop fields. In this instance, the land slope, the land use, and the soil erodibility (K = 0.28) all contributed to the high sediment production within this cell. Cells #232, #335, #403, and #600 all displayed erosion production rates between 3.0 and 4.0 tons/acre (6.7-9.0 MT/ha). The land use within these 4 cells was predominantly row-crop agriculture. The soils within these areas were mostly Wawasee loams and the average land slope of these cells was in excess of 7.5%. Cells #275, #335, and #403 are within the Fish Lake subwatershed while #232, and #600 are within the subwatershed of Royer Lake.

Nutrient Loading

The AGNPS model supplied estimates for nitrogen and phosphorus concentrations in runoff from the watershed. Values were produced both for sediment-bound and for soluble forms of the nutrients. In general, areas exhibiting high outputs of sediment-bound nitrogen will also exhibit high outputs of sediment-bound phosphorus. This observation is also true for the soluble components of nitrogen and phosphorus. For this reason the following discussion of nutrient inputs is presented as an analysis of nutrient inputs to each lake by the respective sediment-bound and soluble forms. Important to this discussion is the realization that while each lake has its own distinct subwatershed, some fraction of the nutrients entering Royer Lake are eventually transported to Fish Lake via streamflow. The model furnished predictions for the entire watershed and for individual cells. Modeled results for soluble nitrogen and phosphorus are presented in Figures 3-16 and 3-17. Sediment-bound nitrogen and phosphorus results are displayed in Figures 3-18 and 3-19.

Fish Lake Nutrients: Using cumulative data generated by the AGNPS model for those cells bordering Fish Lake, it was possible to calculate the total phosphorus and nitrogen (i.e., soluble N and sediment-

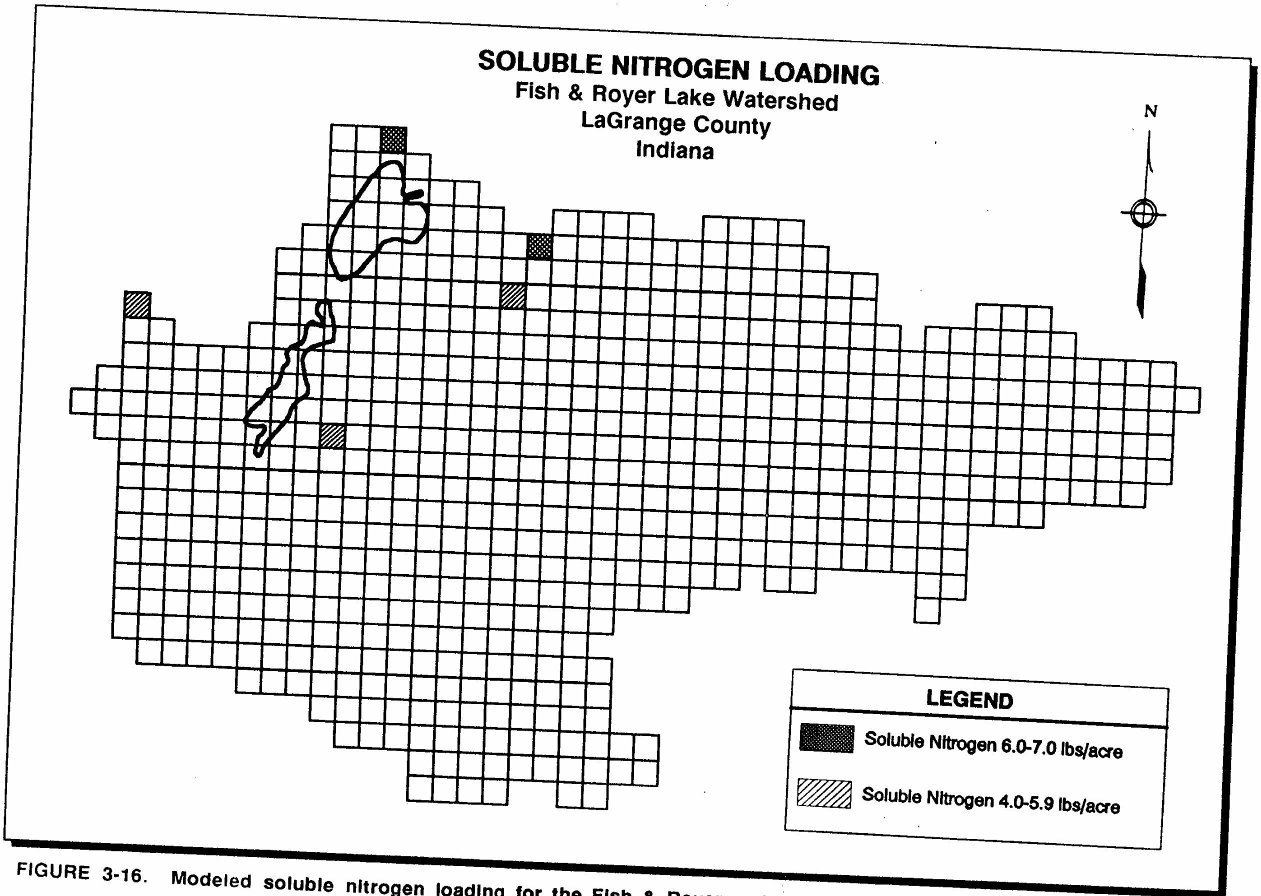


FIGURE 3-16. Modeled soluble nitrogen loading for the Fish & Royer watershed.

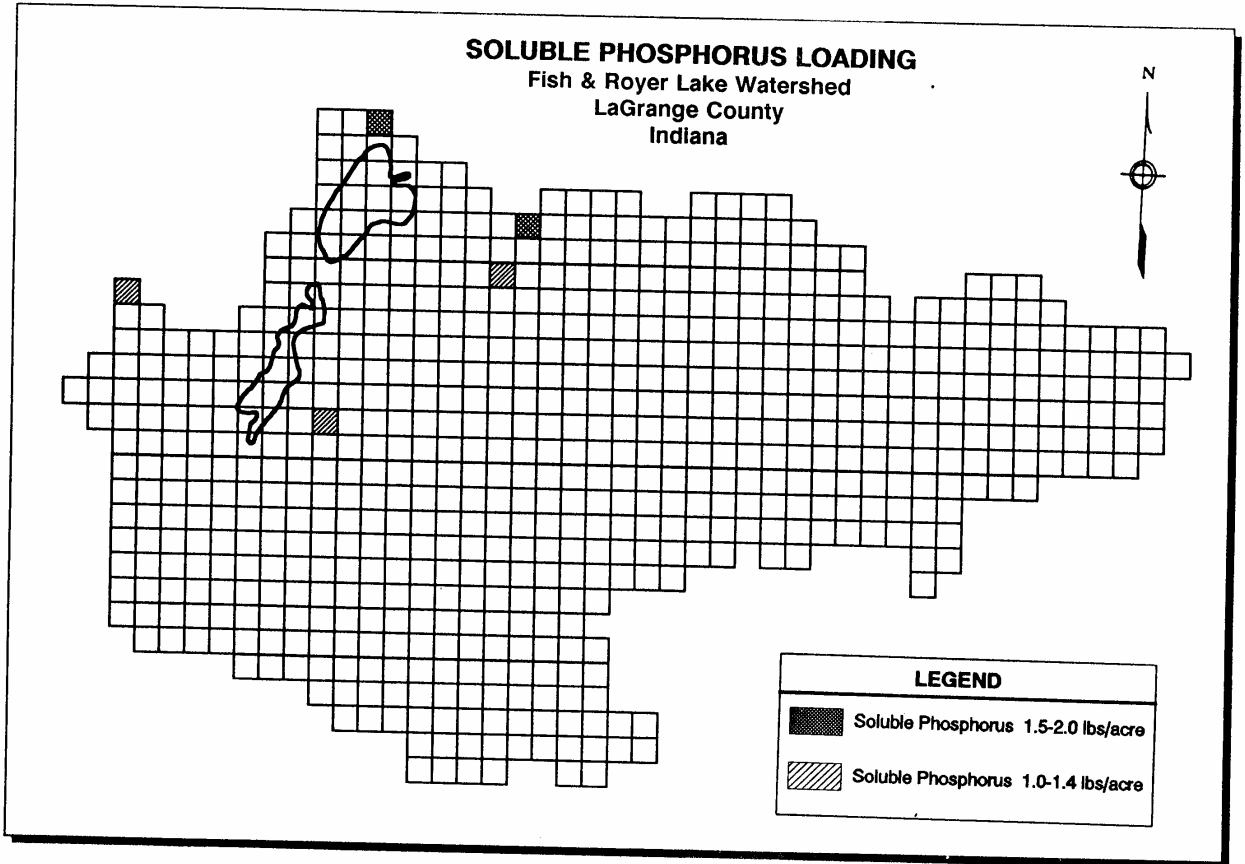


FIGURE 3-17. Modeled soluble phosphorus loading for the Fish & Royer watershed.

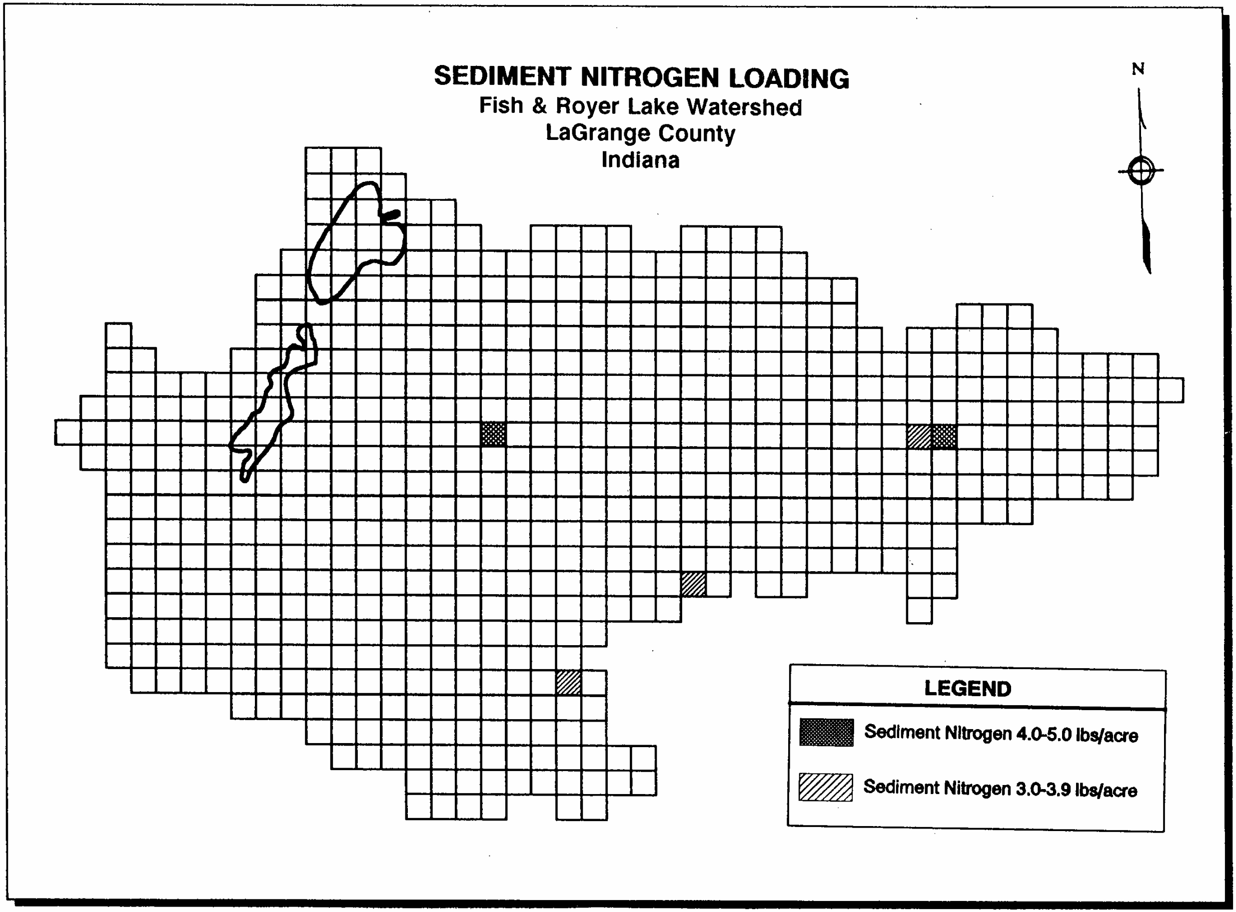


FIGURE 3-18. Modeled sediment nitrogen loading for the Fish & Royer Lake watershed.

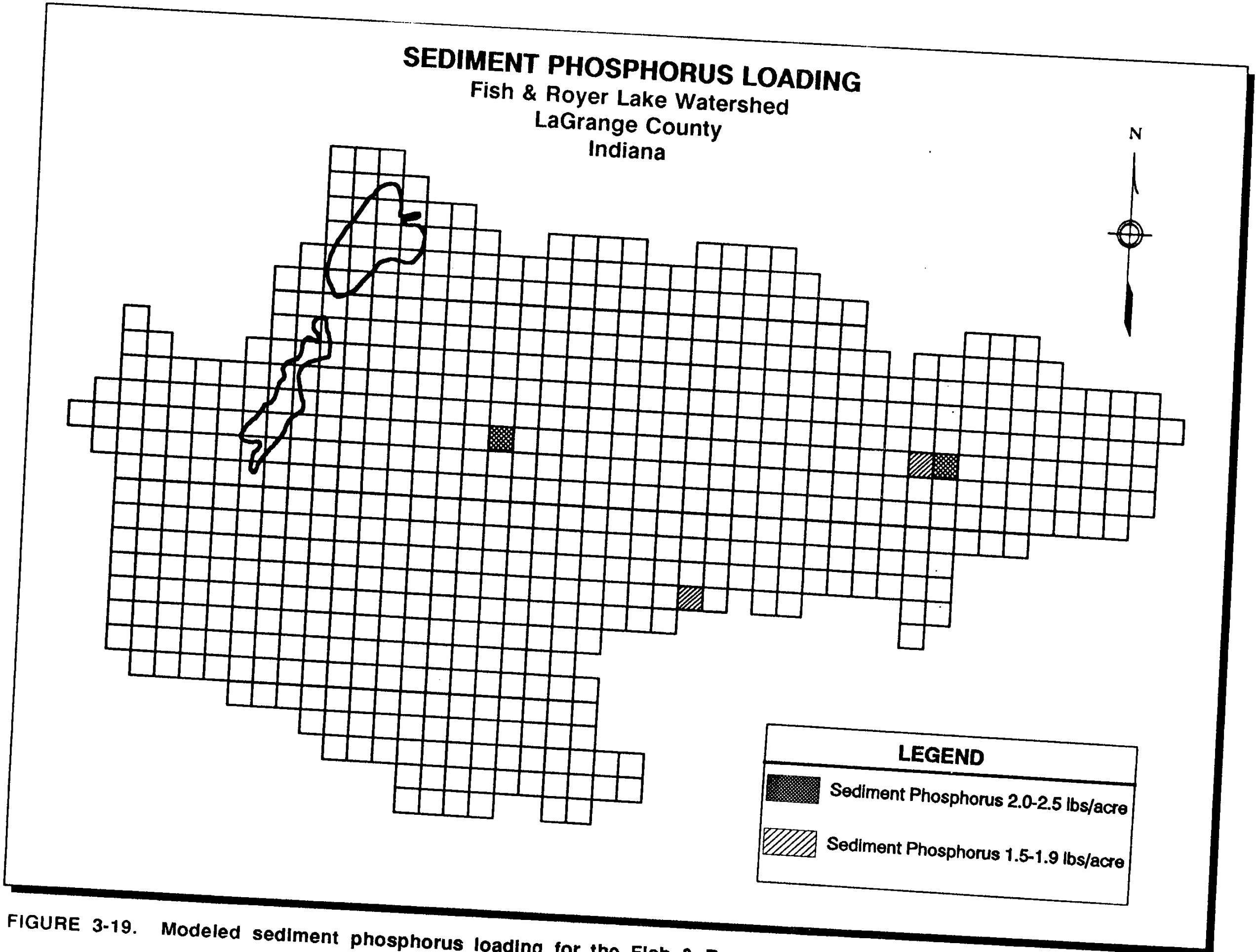


FIGURE 3-19. Modeled sediment phosphorus loading for the Fish & Royer Lake watershed.

bound N) loading to Fish Lake during the design storm. Total nitrogen loading was 4.00 tons (3.63 MT). Approximately 87% of this amount, 3.48 tons (3.16 MT), was in the form of soluble nitrogen. Total phosphorous loading to Fish Lake was determined as 0.93 tons (0.84 MT). Soluble phosphorus accounted for approximately 71% of this amount. Two characteristics of the Fish Lake watershed may explain the relative importance of the soluble nutrient component observed. First, the watershed contains primarily agricultural land use patterns. Surface water runoff concentrations of total nitrogen from continuous corn production may reach as high as 131 mg/L (Burwell et al., 1975). Second, inputs of sediment to Fish Lake are lowered due to the presence of upstream wetlands, such as Grass Lake, and by Royer Lake serving as a sediment basin to the south. Therefore, the sediment-bound component of nitrogen is correspondingly lowered and its relative impact lessened.

The concentration of soluble nitrogen exported from individual cells ranged from no export to 6.92 pounds/acre (7.75 kg/ha). Cells #3 and #38 exported the highest amounts of soluble nitrogen. In these cells, all of the nitrogen exported was generated within the cell. Cell #83 exported 4.96 lbs/acre (5.56 kg/ha). These three cells also exhibited the highest export of soluble phosphorus to Fish Lake. The range of values generated for soluble phosphorus was 0.0 lbs/acre to 1.51 lbs/acre (1.69 kg/ha). Cells #3 and #38 both exported the highest concentrations of soluble phosphorus, while Cell #83 exported 1.03 lbs/acre (1.15 kg/ha). Cell #3 is situated just north of Fish Lake and west of the intersection of 100 South Road and 500 East Road. Slightly more than 90% of this cell is utilized for row crop agriculture. The soil type is divided between Adrian muck and Wawasee fine sandy loam. Muck soils that are used for agriculture are susceptible to high soluble nutrient exports due to rapid runoff caused by inundated and partially unvegetated soil surfaces and fertilization. Cell #38, located approximately 3,000 feet east of Fish Lake and midway between 100 and 200 South Roads, is 100% rowcrop agricultural and partially Sebewa loam and Boyer loamy sand. Sebewa loam is very poorly drained and exhibits some of the same characteristics described above for Adrian muck. Cell #3 and Cell #38 also exhibited the highest hydrologic runoff volumes found in the Fish Lake watershed. High hydrologic flushing allows less time for soils and vegetation to assimilate soluble nutrients. Cell #83 is also 100% rowcrop agriculture with a similar combination of poorly drained and Boyer loamy sand soils.

The amount of sediment-bound nutrients exported by an area is strongly correlated to the quantity of sediment exported. Sediment-bound nitrogen conveyed from individual cells within the Fish Lake watershed ranged from 0.0 pounds/acre (0.0 kg/ha) to 4.78 pounds/acre (5.35 kg/ha). The highest value was observed in Cell #275, the cell that also exhibited the highest erosion rate in the watershed (see physical description under "Cell Erosion"). The sediment erosion rate within this cell was 7.49 tons/acre (16.79 MT/ha). Cell #293 exported 4.07 lbs/acre (4.56 kg/ha) of sediment-bound nitrogen. Cell #514 conveyed 3.45 pounds/acre (3.86 kg/ha) and Cell #292 exported 3.15 pounds/acre (3.53 kg/ha). Conveyance of sediment-bound phosphorus ranged from 0.0 ponds/acre to 2.39 pounds/acre (2.68 kg/ha). Cell #275 exhibited the highest phosphorus export within the Fish Lake watershed. Cell #293 exported 2.04 ponds/acre (2.29 kg/ha), Cell #514 exported 1.73 pounds/acre (1.94 kg/ha), and Cell #292 exported 1.58 pounds/acre (1.77 kg/ha). Cell #293 contains an overall 5.9% slope, is 97% rowcrop agricultural, and contains both Wawasee fine sandy loam (2-6% slopes) and Conover loam (0-3% slopes). Cell #514 is located between 600 and 750 East Roads and south of 300 South Road. The slope within this cell is

5.0%; the land use is 70% rowcrop agriculture; and the dominant soil type is Conover loam. Cell #292, situated directly west of Cell #293, has a 6.3% slope; is 80% rowcrops; and is dominated by Wawasee fine sandy loam (6-12% slopes).

Royer Lake Nutrients: Using cumulative data generated by the AGNPS model for those cells bordering Royer Lake, it was possible to calculate the total phosphorus and nitrogen (i.e., soluble N and sediment-bound N) loading to Royer Lake during the design storm. Total nitrogen loading was 4.23 tons (3.84 MT). Approximately 56% of this amount, 2.37 tons (2.15 MT), was in the form of soluble nitrogen. Total phosphorous loading to Royer Lake was determined as 0.63 tons (0.57 MT). Soluble phosphorus accounted for approximately 70% of this amount. The importance of the soluble nutrient component observed was somewhat less than that found in the Fish Lake subwatershed. The soluble component may be a smaller fraction of the total nitrogen input because of the presence of less sediment depositional areas in the Royer Lake subwatershed. Sediment depositional areas may include topographic features (e.g. depressions) or vegetative features (e.g. forests and wetlands) that reduce storm runoff and trap sediments. The AGNPS model recognizes these areas by various cell characterizations including slopes and soil textures.

The concentration of soluble nitrogen exported from individual cells within the Royer Lake subwatershed ranged from no export to 5.56 pounds/acre (6.64 kg/ha). Cell #101 and #311 each exported the highest amounts of soluble nitrogen. In these cells, all of the nitrogen exported was generated within the cell. These two cells also exhibited the highest export of soluble phosphorus to Royer Lake. The range of values generated for soluble phosphorus was 0.00 pounds/acre to 1.03 pounds/acre (1.15 kg/ha). Cell #101 and #311 each exported 1.03 pounds/acre (1.15 kg/ha). Cell #101 is situated in the along the northwestern edge of the watershed west of 400 East Road and north of 200 South Road. The land use within this cell is 100% row crop agriculture. The overall slope is 2.8% on Conover loam soils. Cell #311 is primarily utilized for rowcrop agriculture (97%) and is also covered by Conover loam soils. Its slope is slight at 1.5%.

Sediment-bound nitrogen conveyed from individual cells within the Royer Lake watershed ranged from 0.00 pounds/acre (0.00 kg/ha) to 3.42 pounds/acre (3.83 kg/ha). The highest value was observed in Cell #600, a cell that also exhibited a high erosion rate in the watershed. The sediment erosion rate within this cell was 3.79 tons/acre (8.49 MT/ha). Conveyance of sediment-bound phosphorus ranged from 0.00 pounds/acre to 1.71 pounds/acre (1.92 kg/ha). Cell #600 also exhibited the highest phosphorus export within the Royer Lake subwatershed. Cell #600 contains an overall 8.3% land slope; is 72% rowcrop agricultural, and is primarily comprised of Wawasee fine sandy loam (2-6% slopes).

Hydrology

The AGNPS model was also used to examine hydrologic inputs to both Fish and Royer Lakes. Results for both lakes are presented below. Watershed cells producing high runoff are displayed in Figure 3-20.

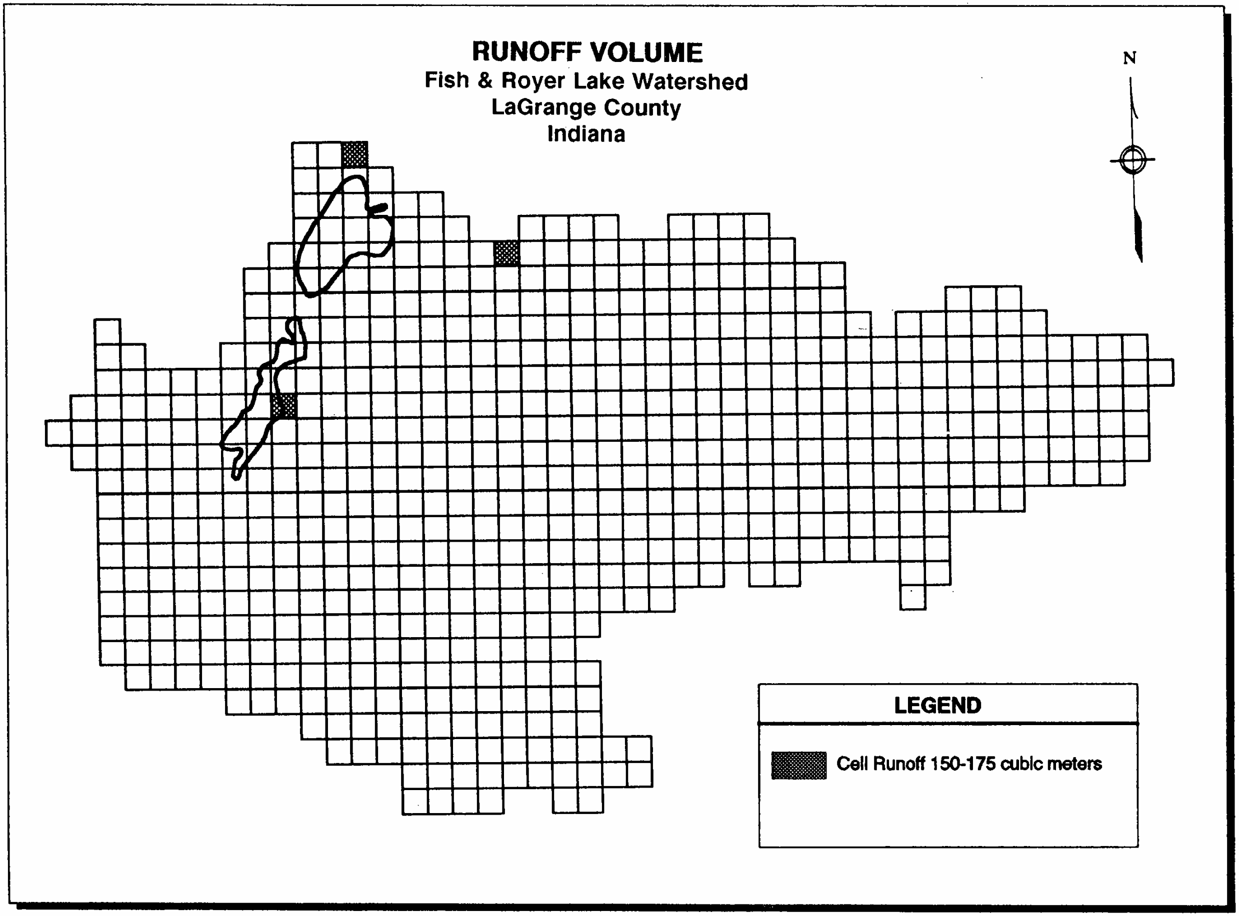


FIGURE 3-20. Modeled cell runoff for the Fish & Royer Lake watershed.

Fish Lake: Hydrologic input to Fish Lake was estimated to be 2.52 x 10^7 ft^3 (7.14 x 10^5 m^3). The areas that contributed the greatest volume per acre, 5,917 ft^3 (168 m^3), were Cells #3 and #38. Cell #3, located north of Fish Lake along 500 East Road, is utilized primarily for rowcrop agriculture. Cell #38, located approximately 3,000 feet east of Fish Lake and midway between 100 and 200 South Roads, is comprised entirely of rowcrop fields. Their high hydraulic contribution is believed to be the result of runoff from agricultural lands associated with seasonally inundated soils.

Royer Lake: AGNPS estimated hydrologic inputs to Royer Lake to be 1.39 x 10^7 cubic feet (3.93 x 10^5 m^3). Cell #223, located midway down the eastern shoreline of Royer Lake, was highest per-acre source of runoff to Royer Lake. This cell generated 5,627 ft^3 (159 m^3) of runoff. Runoff from Cell #223 was believed to be high due to moderate (4.5%) slopes associated with seasonally inundated soils.

3.3.6 Septic System Phosphorous Inputs

Construction of a predictive framework for the estimation of loading from septic systems to aquatic systems, especially where data are incomplete, requires a number of assumptions. The assumptions made to produce the results presented in this study are listed below. Further descriptions of these assumptions are presented in subsequent text.

- Residences are full-time (year-round) and are occupied approximately 90% of the year.
- The age of the septic system is the same as the age of the home.
- Udorthent soils adjacent to the lake are primarily saturated and mixed with muck.
- The average person produces 169 liters (44.6 gal.) of wastewater per day.
- The phosphorous concentration in that wastewater is 5 mg/l.
- The tank portion of the septic system is regularly maintained and retains a constant 42.5% of the phosphorus entering it for the life of the system.

The input of phosphorus from septic fields located in the vicinity of a lake may be significant. Because these systems are subject to limited capacity and frequent high water tables, elevated concentrations of phosphorus may be transported to the waterway via groundwater. Factors that influence nutrient export from septic systems to a nearby surface water body include: (1) capacity of leach field soils to attenuate nutrients; (2) distance between leach fields and the lake; (3) number of people using septic systems; and (4) per-capita inputs to septic systems.

The attenuation capacity of the soil is the first important factor influencing the nutrient load from septic systems. This value can be represented by a "nutrient retention coefficient" that ranges from 0.0 (no retention) to 1.0 (complete retention) and indicates percent of the total septic input immobilized by a septic tank/leach field combination. Retention coefficients are influenced by soil drainage, permeability, slope, soil type, and soil pH. System age, maintenance levels, rainfall frequencies, and plant uptake also affect attenuation.

Homes located along the perimeter of Fish Lake are mostly situated within a band of Udorthents, a soil type consisting of fill material mixed with existing soils. Typically, in areas surrounding lakes, the soils are underlain with chalk or marl. The Soil Survey of LaGrange County reports that commercial sewers are generally needed in these areas. Due to the variability of these soils, most suitability and physical characteristics are not listed in the soil survey. Seasonal high water tables are considered to be at a depth of 3 to 6 feet.

Residences situated in the zone between Fish and Royer Lakes were constructed within a large pocket of Houghton muck, a soil listed by the LaGrange County Soil Survey as "severe" (the worst categorization) for construction of septic systems. Seasonal high water tables are at a depth of 0.5 to 1.0 feet. Muck soils are poor choices for leach fields because soil water saturation results in anoxic conditions that limit the processes that bind nutrients. Soils below the water table by exhibit a 50% decrease in phosphorus adsorption (University of Michigan Biological Station, 1974). In addition, the high water table associated with these soils tends to "flush" waste materials directly into adjacent bodies of water before they can be bound to soil particles.

Homes associated with Royer Lake are situated primarily within Udorthents, and Houghton and Palms mucks. Much of the western shore, however, is bordered by moderately sloping Boyer loams. While the seasonal high water table is generally below 6 feet deep for Boyer loams, the limitation is "severe" for septic leach fields because the filtering quality of the soil is poor. Ground-water contamination is possible in some areas because of the moderately rapid permeability.

The estimated attenuation of phosphorus originating from lake dwellings was based on the age of septic systems. Ellis and Childs (1973) reported that in new systems, most of the phosphorus was bound by the soil within a few feet of the leaching field. When the septic system aged, however, its capacity to immobilize phosphorus was reduced as soil binding sites became saturated with the nutrient. Under such conditions, phosphorus traveled farther and reached the lake more quickly. Eventually, the phosphorus adsorption capacity of the soil was exceeded, the system failed, and all of the entering phosphorus passed through the soil and into the receiving water body. Sawhney and Hill (1975) and Sawhney (1977) observed that in new systems, most of the effluent is fixed within a few feet of the drain field, while in older systems, increasingly larger concentrations of phosphorus may move through the soil, into the groundwater, and then into the lake. Thus, as a system becomes older, the nutrient-binding capability of the soil is exhausted, and the attenuation of nitrogen and phosphorus is reduced.

Often, records reflecting the age of septic systems are not available and surrogate figures must be used. For the purposes of this study, septic system ages were assumed to be the same as the ages of the residences they served. Construction dates for homes bordering Fish and Royer Lakes were obtained from the LaGrange County Assessor's Office. Where this information was unavailable, construction dates were estimated from the ages of neighboring residences. The average ages of homes along Fish and Royer Lakes was 24 years and 27 years, respectively.

Hill and Frink (1974) investigated the longevity of septic systems in various soil types and defined the "half-life" of a septic system as the average number of years required for the cumulative failure rate (for the total population of septic systems) to reach 50%. The researchers found that the half-life for all glacially-derived soils was 27 years. For poorly-drained soils, the half-life was determined to be 25 years. Discussions with the LaGrange County Board of Health suggested that a more realistic estimate of the half-life of systems in the muck soils along Fish and Royer Lakes would be considerably less than 25 years, perhaps as low as 5 years. An intermediate value of 7.5 years was chosen as the half-life in mucks and lakeside Udorthents. The 27 year figure was assigned to the homes on Fish Lake that were built on Boyer loams. Assuming a linear relationship between the age of a system and the amount of phosphorus retained, new systems located in glacially-derived soils would attenuate 100% of the phosphorus entering them, 27 year old systems would attenuate 50% of the phosphorus, and 54 year old systems would attenuate 0% of the phosphorus. Similarly, new systems in muck soils would retain 100%, 7.5 year old systems would retain 50%, and 15 year old systems would retain 0%. Half-life designations and retention figures for Fish and Royer Lake sites are presented in Table 3-27.

Table 3-27. Half-life designations and retention figures for Fish and Royer Lake residences.

Lake	Soil Type	Average System Age (YRS)	Half-life (YRS)	Drain Field P Retention (%)
Fish	Houghton muck	24.3	7.5	0.00
Fish	Udorthrents	24.3	7.5	0.00
Royer	Houghton muck	26.7	7.5	0.00
Royer	Udorthrents	26.7	7.5	0.00
Royer	Boyer loam	26.7	27.0	44.99
Royer	Palms muck	26.7	7.5	0.00

It should be noted that approximately 42.5% of the phosphorus entering a septic system is removed in the septic tank before the wastewater reaches the drain field (Reckhow et al., 1980; Sawheny and Hill, 1975; Bache and Williams, 1971). Because phosphorus removal processes in septic tanks involve physical settling, the retention efficiency is assumed to remain constant over time, given normal system care. Understanding that 42.5% of the phosphorus entering septic systems is removed in the septic tank, it is reasonable to conclude that the remaining 57.5% enters the drain field. Therefore, the phosphorus retention figures listed in Table 3-27 are applied to only 57.5% of the total phosphorus produced in households.

Distance between septic systems and the water body is the second important factor in determining septic impacts to a lake. Generally, as the distance between a water body and a septic system increases, the amount of nutrients reaching the water body from the system decreases. For Fish and Royer Lakes, only those systems situated directly adjacent to the lake were evaluated for septic loading.

The number of people using septic systems in the watershed is the third important factor in determining septic loading to a lake and can be represented by a "capita-year" figure. This value combines estimates of permanent and seasonal populations, the number of septic systems used, and the fraction of the year the systems are used. A capita-year is essentially the average number of residents per dwelling unit, multiplied by the number of dwelling units, multiplied by the fraction of a year the residents are home.

Capita-years for the Fish/Royer watershed were calculated using data supplied by the US Census Bureau in Chicago. An interview with officials in that office revealed that the average household in LaGrange County contained 3.17 full-time resident persons. Because reliable data for seasonal occupancy of the dwellings around the lakes were unavailable, it was assumed that all residences were year-round. The capita-year figures for the lakes in this study are presented in Table 3-28.

Table 3-28. Capita year data for Fish and Royer Lakes.

Lake	Soil Type	Number of Dwellings	Number of Residents[a]	Time at Home[b]	Capita Years
Fish	Udorthents	60	190	90%	171
Fish	Houghton muck	24	76	90%	68
Royer	Udorthents	90	285	90%	257
Royer	Houghton muck	15	48	90%	43
Royer	Boyer loamy sand	24	76	90%	68

[a] Number of residents = number of dwellings * number of residents per dwelling (i.e., 3.17).

[b] Time at home = fraction of year residents are at not on vacation, extended trips, etc.

The fourth important factor influencing septic loading is per-capita nutrient input to septic systems. This value is simply the nutrient mass, per capita, per year that enters a septic system and is the aggregate of inputs from toilets, showers, basins, laundry rinse, and other household waste water. It is often represented by an export coefficient in kg/capita-year. A review of the literature revealed that the average person produces 44.6 gallons (169 l) of waste water per day (Chan, 1978; Brandes, 1977; Otis et al., 1974; Bouma et al., 1972; Feth, 1966; Preul, 1964). An intermediate phosphorus concentration for domestic wastewater was found to be 8 mg/l (Metcalf and Eddy, 1979). Two studies conducted in Indiana on raw sewage phosphorous concentrations found 1973-1974 concentrations of between 4.5 mg/l and 5.5

mg/l (correspondence with John Winters, IDEM). Therefore, an average phosphorous concentration of 5.0 mg/l was selected for this evaluation. The calculation for the annual contribution per capita may be summarized as follows:

$$(169\ \mathit{l/day})\ \text{X}\ (5.0\ \mathit{mg\text{-}P/l})\ \text{X}\ (2.205\ \text{X}\ 10^{-6}\ \mathit{lbs/mg})\ \text{X}\ (365\ \mathit{days/yr}) = 0.68\ \mathit{lbs\text{-}P/yr}$$

Thus, the annual total phosphorus production was determined to be 0.68 pounds per capita (0.31 kg/capita).

Total phosphorus production by households adjacent to Fish and Royer Lakes was calculated using the per capita phosphorus production estimate of 0.68 lbs/yr and the number of residents (Table 3-28). The results are presented in Table 3-29, along with values for septic tank retention, and leach field retention. The column labeled "Household P Production" refers to the total amount of phosphorus in wastewater generated by all of the houses situated within a specific soil type. Septic Tank Retention is the amount of that phosphorus that is retained by the septic tank. Leach Field retention is the amount of phosphorus leaving the septic tank and retained in the leach field. Subtracting Septic Tank Retention and Leach Field Retention from Household P Production yields the amount of phosphorus exported from each soil type. Total phosphorous loadings to each water body were calculated in this way, and are listed in Table 3-30. Under current conditions, Fish Lake receives approximately 92.8 pounds (42.1 kg) of total phosphorus from septic systems annually. Similarly, Royer Lake receives approximately 134.7 pounds (61.1 kg) each year.

Table 3-29. Total phosphorus production/retention by household for Fish and Royer Lakes.

Lake	Soil Type	Household P Production	Septic Tank Retention	Leach Field Retention
Fish	Udorthents	52.8/23.9	22.4/10.2	0.2 /0.1
Fish	Houghton muck	21.1/ 9.6	9.0/ 4.1	0.3 /0.1
Royer	Udorthents	79.2/35.9	33.7/15.3	0.7 /0.3
Royer	Houghton muck	13.2/ 6.0	5.6/ 2.5	0.0 /0.0
Royer	Boyer loamy sand	21.1/ 9.6	9.0/ 4.1	3.4 /1.5

NOTE: Estimates reflect annual figures for total phosphorus (lbs / kg).

Table 3-30. Total phosphorus from septic systems to Fish and Royer Lakes.

Lake	Lake Soil Type	Phosphorus Loading (lbs /kg)
Fish	Udorthents	66.6 /30.2
Fish	Houghton muck	26.2 /11.9
Fish Total	All soils	92.8 /42.1
Royer	Udorthents	98.8 /44.8
Royer	Houghton muck	16.7 /7.6
Royer	Boyer loamy sand	19.2 /8.7
Royer Total	All soils	134.7 /61.1

3.4 SOURCES OF SEDIMENTS AND NUTRIENTS

Based on the results of the watershed analysis, storm sampling, and visual observations the dominant sources of sediments and nutrients were identified for both Fish and Royer Lakes. The following sections outline principal sources of each type of pollutant in the watershed.

3.4.1 Sediments

The AGNPS modeling indicated that sediment inputs to both lakes are generated by upland sources in the watershed. Although no specific problem areas were identified, it is reasonable to conclude that the overwhelming majority of sediments originate from activities associated with rowcrop agriculture. In general, the areas with the highest erosion rates, as identified by the AGNPS model, are those that combine intensive-till farming, hilly slopes, and erodible soil types. The five AGNPS cells exhibiting the highest erosion rates had an average land slope of 8.4%; were located on sandy loam soils (K=0.28); and were utilized mostly for rowcrop agriculture. The areas identified were cells #232, #275, #335, #403, and #600.

The transport of sediments from the watershed to the lakes is primarily through stream channels. The largest sediment loads to Fish Lake can be expected in the tributary (FL-2) flowing through AGNPS cells #11, #12, #18, #19, #35, #36, #58, #59, #61, and #63. The largest sediment loads to Royer Lake can be expected in RL-4 flowing through cells #138, #180, and #224. Additional sediment loading to Royer Lake can be expected from RL-5 flowing through cells #349, and #424.

Sampling conducted in the Fish and Royer Lake tributaries following a storm event on September 19, 1989 revealed that the highest sediment loading to Fish Lake was Tributary #2 (FL-2). The tributary transporting the highest sediment concentrations to Royer Lake was Tributary #4 (RL-4). These findings are in agreement with the predicted sediment loadings by the AGNPS model.

Whether originating on agricultural fields or in stream channels, sediment yields vary greatly from storm to storm. Within a given area, the largest annual sediment loads in runoff are often 20 times greater than the minimum sediment loads (NCAES, 1982). Even within the same stream, concentrations of suspended solids can vary by a factor of 10 for a given rate of water discharge. Therefore, even though areas have been identified in this study as potential sediment trouble spots, others that were not captured by this investigation may exist.

3.4.2 Nutrients

Generally, the most important plant nutrients impacting the trophic status of lakes are nitrogen and phosphorus. Based on relatively high N:P ratios in Fish and Royer Lakes (i.e., > 90:1), it was concluded that phosphorus was the limiting nutrient in both water bodies. The following sections present major sources of the plant nutrient in each lake.

Fish Lake

This study identified the following five major sources of phosphorus to Fish Lake.

- Runoff from agricultural practices in the watershed
- Internal loading from lake sediments
- Leachate from septic systems along the lake shores
- Atmospheric deposition
- Outflow from Royer Lake

Runoff: Runoff from agricultural lands is probably the largest contributor of phosphorus to Fish Lake. Using AGNPS, it was estimated that 2,050 pounds (929.9 kg) entered Fish Lake during the design storm (i.e., 2 year, 24 hour event). Of this amount, 71% was estimated to be in the soluble form, and thus, readily available to aquatic plants. The highest contributors of soluble phosphorus to Fish Lake, as identified by the model, were AGNPS cells #3, #38, and #83.

Tributary sampling conducted following a storm event revealed that only 16% of the phosphorus transported by FL-2, and 45% of the phosphorus transported by FL-3 was in the soluble form. The difference between model predictions and the observed data was attributed to the following factors:

- Modeling was performed for the 2 year, 24 hour event; storm sampling was conducted during an event of much greater frequency.
- Modeling results reflect the storm nutrient inputs over the course of the entire event; sampling revealed inputs at a discreet moment in time (i.e., actual input levels and solubility fractions vary considerably over the duration of a runoff event).

Internal loading: Although it was not quantified in this study, nutrient recycling from bottom materials may be considered an important source of phosphorus to Fish Lake due to the high input of sediment from the agricultural watershed. Internal loading most commonly occurs in the Spring and Fall when wind-mediated mixing of phosphorus-rich hypolimnetic (i.e., bottom) waters and surface waters takes place. The phosphorus in hypolimnetic waters is released from sediments during periods of anoxia common during summer and winter. Mixing results in higher surface water concentrations of phosphorus and encourages plant growth in the photic zone.

Septic leachate: The estimated annual phosphorus loading from septic systems, 92.6 pounds (42.0 kg), indicates that septic system inputs are an important source of nutrients to Fish Lake. The consideration of this input as important is based more on the type and distribution of septic phosphorus than the quantity. Inputs from septic system leakage tend to be evenly distributed over time and entirely in a soluble form that is immediately available for biological uptake. This is in contrast to nutrient inputs from the watershed which are principally associated with storms, and are in particulate and soluble forms which may be only fractionally available for immediate uptake by algae and macrophytes.

Atmospheric Loading: Annual atmospheric deposition to Fish Lake was calculated to be 56.9 pounds (25.8 kg). While this addition may be considered significant, there is no practical technology readily available to the Fish & Royer Lake Association for controlling atmospheric deposition.

Outflow from Royer Lake: Outflow from Royer Lake represents a significant input of phosphorus to Fish Lake. Using AGNPS, it was estimated that the input of soluble phosphorus from the tributary leaving Royer Lake was 562.4 pounds (255.6 kg) during the design storm. Tributary sampling of FL-3, however, revealed relatively low dissolved phosphorous concentrations of .005 mg/l.

Royer Lake

This study identified four major sources of phosphorus to Royer Lake. These sources include runoff, internal loading, septic leachate, and atmospheric deposition. Each of these sources are described below.

Runoff: Using AGNPS, it was estimated that 1,260 pounds (572.7 kg) of phosphorus entered Royer Lake during the design storm. Of this amount, 70% was in the soluble form and thus, readily available to aquatic plants. The highest contributors of soluble phosphorus to Royer Lake were AGNPS cells #101 and #311.

Tributary sampling of RL-4 and RL-5 conducted following a storm event revealed that soluble phosphorus accounted for 63% and 91%, respectively, of the total phosphorus transported by these tributaries. The fraction of soluble phosphorus predicted by AGNPS is in general agreement with these field results.

Internal loading: High phosphorus loading from Royer Lake's agricultural watershed may result in nutrient-rich sediments. The bottom sediments of Royer Lake are comprised of sand and muck. These sediments may contain much higher concentrations of phosphorus than the water (Holdren, et al., 1977;

and many others). Anoxic conditions, followed by mixing, can result in significant inputs to surface waters.

Septic leachate: Total phosphorus contributions to Royer Lake from septic systems was calculated to be 134.8 pounds (61.1 kg). Since this source is primarily in the soluble form, it is expected that septic leachate may be an immediately available source of nutrients.

Atmospheric deposition: Annual atmospheric deposition to Royer Lake was calculated to be 39.2 pounds (17.8 kg). This addition, while considered of moderate significance, is not presently manageable.

SECTION 4. SEDIMENT AND NUTRIENT MITIGATION TECHNOLOGIES

An overview of nutrient and sediment mitigation technologies is presented in this section of the report. The discussion focuses on three distinct areas: upland watershed controls; septic system remedies; and in-lake sediment removal. Potential sources of additional information and costs associated with these operations are listed at the end of this section.

4.1 UPLAND WATERSHED CONTROLS

Control of sediment and nutrient inputs in upland areas generally involves installation of various best management practices (BMPs) at a number of locations in the watershed. Because no single area was identified as contributing excessive amounts of these pollutants, and because the sources are located on private agricultural lands throughout the watershed, it is suggested that the Fish & Royer Lake Association encourage and coordinate placement of BMPs through the local office of the LaGrange County Soil and Water Conservation District (SWCD), U.S. Soil Conservation Service (SCS), and the U.S. Agricultural Stabilization and Conservation Service (ASCS), all located in LaGrange, Indiana. A general overview of the available control technologies is presented below.

4.1.1 Sediment Control Methods

The control of erosion and sedimentation requires an understanding of the underlying causative mechanisms. Water erosion, as evident in the Fish and Royer watershed, is the result of detachment of soil particles either from the impact of raindrops or from the shear forces of water as it flows across the surface of the ground. The principal mechanism at work at the field level, however, is raindrop impact (NCAES, 1982). In addition to causing particle detachment, splashing raindrops tend to break down soil aggregates into smaller pieces which are more readily carried in runoff. Furthermore, the force of the falling raindrops can lift particles into overland flow that would not otherwise be transported. These particles tend to travel a short distance downslope before settling back to the soil surface. Repeated impacts of raindrops can cause significant particle movement.

Sedimentation occurs when the carrying capacity of overland flow is exceeded and particles begin to settle, usually as the result of reductions in flow velocity. Larger-grained sediments and aggregates are deposited first, with finer-grained sediments falling out as velocity decreases. Pools or bends in stream channels where the velocity of flowing water is diminished often serve as sinks for eroded upland soil. Similarly, lakes can experience extensive loss of depth at the mouths of tributaries where flowing water enters standing water.

It has been found that deposition of sediment can actually increase the energy potential of flowing water, causing more detachment and transport in downstream areas. McDowell and Grissinger (1976) discovered that upland control measures that decrease soil loss more than runoff actually created channel instability lower in the watershed. Because pools and bends in stream channels often serve as sinks for sediments, if upland soil erosion is reduced without corresponding reductions in runoff, these areas may become scoured, producing high sediment yields for several years while the stream system comes back to an equilibrium. For this reason, sediment control measures that decrease runoff volume are generally more effective in improving the water quality of receiving bodies (i.e., lakes).

Although it is true that controlling erosion will control sediment, there are some key differences from a management perspective that influence the choice of an appropriate mitigative approach. The most important of these differences is that erosion can only be controlled at its source while sedimentation can be managed potentially at any point between the source and the receiving body. Logically, therefore, sediment control strategies are usually separated into two general categories: (1) those that reduce the amount of field erosion, and (2) those that reduce the sediment delivery to receiving systems. Selection of appropriate combinations of control measures depends on the objectives of the mitigation. Controlling erosion has impacts on agricultural productivity (sometimes positive and sometimes negative) and on water quality. Controlling sediment, however, generally affects only water quality.

Numerous erosion/sediment control strategies have been initiated under the direction of the SCS. The most common of these techniques are briefly described, below.

<u>Conservation Tillage Systems</u>: Techniques covered under this title include no-till agriculture, minimum-till agriculture, sod-crop planting, chisel plowing, and slot planting. These practices generally reduce the volume of surface runoff and prevent erosion by reducing the amount of soil left without protective vegetative cover. Soil loss reductions of up to 99% have been observed for conservation tillage systems (NCAES, 1982). A major benefit to farmers in the Fish and Royer Lakes area is that conservation tillage increases the infiltration capacity of the soil, thereby counter-balancing the large volumes of water potentially lost through evapotranspiration. Because these strategies often require more precise timing of crop-related activities (e.g., soil turning, agrochemical application) than traditional practices, farmers using conservation systems must be prepared to allocate more resources to planning and management. With proper attention to details, however, initial increases in production costs (i.e., fertilizers, pesticides) can be offset by benefits associated with long-term maintenance of soil productivity.

<u>Contour Farming</u>: Techniques covered under this title include plowing, planting, and cultivation along elevation contours. Rows are arranged to run perpendicular to the slope so that the velocity of flowing water does not become too great. Ridges and furrows can be added to allow small-scale ponding of surface water, resulting in more infiltration and less runoff. This method is best used on slopes of less than 8% and in areas with minimal depressions and gullies. These conditions are met in the Fish and Royer watershed.

<u>Cover Crops</u>: Techniques under this title include planting a crop of close-growing grasses, legumes, or small grains during the non-growing season to protect the soil on fields where cash crops are tended

during the growing season. The cover crop not only provides vegetative protection to the soil, but also can be used to build field fertility and cash crop production when using nitrogen-fixing, leguminous cover. In areas where spring conditions are often wet, cover crops can facilitate the soil drying rate through increased evapotranspiration, thereby enabling more timely planting of the cash crop. In northern regions, however, evapotranspiration can slow warming of the soil and delay planting of the cash crop. These two effects must be balanced when considering this technique.

Diversions: Techniques under this title are designed to create channels across the slope with a supporting ridge along the downhill side. The purpose is to reduce the soil transport capacity of runoff by reducing the slope length (i.e., reducing runoff velocity). Diversions are also used to protect sensitive downslope areas from increased erosion or sediment deposition that might result if flows were not diverted. This measure yields the best results if used in conjunction with some other sediment control mechanism.

Grassed Waterways: Techniques under this title include construction of vegetated areas in natural depressions or along field borders where runoff tends to concentrate. These structures act to prevent rill and gully formation. They also reduce flow velocity and physically filter sediment from runoff, causing in-field deposition of sediments. This practice yields the best results if used in conjunction with some other sediment control strategy.

Grass/Legume Rotation: Techniques under this title involve planting a sod crop during one year of a three or four year rotation. This strategy has been shown to reduce soil loss by 80% relative to continuous corn (NCAES, 1982). Rotating crops improves the soil structure, organic matter content, and infiltration capacity when compared to continuous row cropping. In many instances, cash crop yields during "in" years are greater on fields that have been under previous grass/legume rotation.

Sediment Basins: Techniques under this title include construction of basins or depressions to retain sediments that have already been detached and transported from the field, before they reach a sensitive stream or lake. Sediment basins are extremely effective in trapping small-sized particles due to dramatic reductions in flow velocity associated with such basins. Because little or no sediment is produced from small rainfall events, these structures are best used as a back-up to on-site controls for severe storms.

Stream Channel Stabilization: Techniques under this title include the installation of slotted board fencing, concrete jacks, and/or stone riprap along stream channels to reduce bank and bed erosion. These measures are aimed at controlling impacts from upland strategies that decrease soil loss without reducing runoff volume. A thorough knowledge of the original conditions in the stream channel is necessary, however, to determine what changes will result from upstream activities.

Terraces: Techniques under this title are designed to reduce slope length and steepness, thereby diminishing sediment transport capacity. Terraces may be placed into one of two categories: (1) those that are graded to divert water into a grassed waterway or similar structure, and (2) those that are level to hold water on the field and increase infiltration. Although these structures can be quite effective, outlays for construction may not allow this alternative to be cost-effective.

Filter Strips: Techniques under this title involve planting strips of vegetative cover along field borders and stream corridors to intercept sediment before it can enter a water body. Filter strips are probably most effective when used in conjunction with erosion prevention measures since their sediment retention capacity can be easily exceeded during intense runoff events.

Generalized cost estimates for selected BMPs are presented in Table 4-1. Although these techniques were developed to reduce sediment production on agricultural fields, the same principles can be used by homeowners around the lake. Every effort should be made to reduce sediment inputs to both Fish and Royer Lakes. Contributions from residential areas and construction sites can be significant.

4.1.2 Nutrient Control Methods

Nutrient control strategies center on reducing the concentration of fertilizer and animal waste constituents in runoff. Techniques that focus on controlling sediment-bound forms of nitrogen and phosphorus generally also focus on controlling erosion/sedimentation and have been discussed in the previous section. The following paragraphs will also present measures for reducing the soluble fraction of these pollutants.

Two strategies for reducing potential nutrient enrichment of aquatic systems should be used in agricultural watersheds: (1) apply only enough fertilizer for use by crop or lawn plants, and (2) prevent excess nutrients from entering receiving waters. Because nutrients are available from many sources in addition to commercial fertilizer (e.g., animal waste, cut vegetation, crop residue), it is important to use both strategies in a complementary manner.

In order to apply enough fertilizer to support the crop or lawn plants without adding excessive amounts that will ultimately be transported by runoff, it is necessary to understand fertilizer uptake efficiency. Generally, uptake rates range between 50-70% but can be higher than 80% under good conditions (NCAES, 1982). In most cases, under-fertilization is much more noticeable in the short-term than is over-fertilization. The key incentive for a farmer or homeowner to understand uptake efficiency is reduction of costs associated with the purchase and application of commercial fertilizers. The following techniques can be used to increase the efficiency of fertilizer application and uptake.

Soil Testing: Regular soil testing is an essential component of soil fertility management. Soil tests are used to estimate the quantity of available plant nutrients and to make recommendations about fertilizer and lime application. No commercial fertilizer should be applied without adequate testing of pre-existing soil conditions.

Table 4-1. Cost estimates for selected erosion/sediment control strategies.[1]

Conservation Practice	Areal Units	Flat Rate Install. Costs $	Life-span Yrs.	Annual O&M % Costs	Annual Total Costs $
Conservation Planting					
Contour	Acre	10.00	10	5.00	2.23
Field	Acre	5.00	10	5.00	1.12
Wind-10 rod strips	Acre	4.00	10	5.00	0.89
11-20 rod strips		3.00	10	5.00	0.45
21-30 rod strips		2.00	10	5.00	0.45
Contour Farming	Acre	3.00	Annual	None	3.35
Critical Area Planting					
Shaping	Acre	200.00	25	3.00	30.62
Seed, Seeding Fertilizer, lime	Acre	220.00	25	3.00	33.68
Mulching (straw) (Anchored by treading)	Acre	425.00	1	0.00	473.88
Sodding	Sq. Yard	2.50	5	3.00	0.38
Pasture and Hayland Cover					
Tame species seeded with companion crop	Acre	130.00	15	3.00	22.48
Tame species with seedbed preparation	Acre	140.00	15	5.00	27.01
Native species with seedbed preparation	Acre	100.00	15	5.00	19.29
Interseeding with legume	Acre	85.00	6	5.00	24.63
Diversion (includes seeding/ mulching)	L. Feet	2.50	10	5.00	0.56
Grassed Waterway or Outlet (Includes seeding/mulching)	Acre	2000.00	10	3.00	406.75

Table 4-1. Cost estimates for selected erosion/sediment control strategies[1] (Concluded).

Conservation Practice	Areal Units	Flat Rate Install. Costs $	Life-span Yrs.	Annual O&M % Costs	Annual Total Costs $
Grasses and Legumes in Rotation	Acre	Considered as a production cost for crops.			
Sediment Basin	Cu Yard	1.25	25	5.00	0.22
Water & Sediment Control Basin	Cu Yard	2.00	15	5.00	0.39
Grade Stabilization Structure (4' Overfall)					
Rock Chute	Job Est.	1,500.00	25	3.00	229.65
Aluminum:					
< 170 CFS	Job Est.	3,200.00	25	3.00	489.91
> 170 CFS	Job Est.	4,800.00	25	3.00	734.87
Concrete Block Toewall	Job Est.	2,500.00	15	3.00	432.31
Reinforced Concrete	Job Est.	3,250.00	40	3.00	476.12
Wood	Job Est.	2,250.00	20	3.00	359.34
Concrete Block Chute	Job Est.	1,800.00	25	3.00	275.58
Grade Stabilization Structure (6' Overfall)					
Aluminum	Job Est.	8,000.00	25	3.00	1224.78
Wood	Job Est.	5,000.00	20	3.00	798.52
Reinforced Concrete	Job Est.	9,000.00	40	3.00	1318.48
Rock Chute	Job Est.	2,500.00	25	3.00	382.74
Concrete Block Chute	Job Est.	3,000.00	20	3.00	479.11
Mulching (Anchored by)					
Treading	Acre	300.00	2	None	8.19
Netting	Sq Yard	0.30	5	None	0.08
Asphalt Emulsion	Acre	400.00	5	None	109.59
Mulch Blankets	Sq Yard	1.00	2	1.00	0.60
Pasture and Hayland Management					
Pasture Continuous grazing	Acre	18.00	Annual	None	20.07
Rotation grazing	Acre	33.00	Annual	None	36.80
Terrace					
Gradient	L. Feet	1.50	20	2.00	0.22
Broadbased Parallel	L. Feet	2.75	15	2.00	0.45
Narrow Parallel	L. Feet	1.50	15	2.00	0.24
Grassed Back Slope	L. Feet	2.00	20	2.00	0.30
Riser Inlets	Each	50.00	20	5.00	8.99
Field Border/Filter Strips					

Liming: The pH of the soil is a key element influencing fertilizer utilization by crop and lawn plants. Soils that have a high organic content (e.g., mucks), high levels of exchangeable aluminum, or that have received heavy doses of ammonium fertilizers are often too acidic for efficient uptake of nutrients. Raising the pH to proper levels can optimize phosphate use, increase nitrogen fixation, reduce aluminum toxicity, control potash leaching, and mitigate micronutrient deficiencies.

Correct Timing: Timing of fertilizer application can be critical in determining the efficiency of nutrient uptake, crop yield, and lawn performance. Each plant species has a unique pattern of nutrient absorption and it is possible to maximize nutrient utilization by applying the fertilizer near the time of maximum growth. Crop type, date of planting, and soil conditions all affect the optimum timing of application. It is critical to tailor fertilization schedules to meet the demands of site-specific crops under site-specific conditions.

Correct Application Rate: It is important that neither nitrogen nor phosphorus be applied at rates higher than those derived from soil tests or other legitimate estimates. Fertilizers should be used only to provide nutrients not present in adequate amounts for optimum crop or grass production. Using too much fertilizer not only causes nonpoint source pollution, it also increases farm production costs, reducing farm profitability.

Correct Application Method: The method of application is important in determining the amount of nutrients exported from a field in runoff. Generally, broadcast fertilization is much more likely to result in nutrient contributions to runoff. Methods that either inject the fertilizer below the soil surface (e.g., knifing) or cover the fertilizer once it has been broadcast (e.g., disking) consistently reduce the amount of nutrients reaching surface waters. It is best to find methods that place the correct nutrient "dose" in the location where it will do the most good.

The second strategy for controlling nutrient runoff involves preventing the pollutants from reaching a water body. The following general recommendations for reducing the transport of phosphorus were adapted from NCAES (1982):

1. Contouring, terraces, sod-based rotations, and conservation tillage significantly reduce edge-of-field losses of particulate-bound phosphorus because they reduce erosion.

2. Sod-based rotations are particularly effective at reducing losses of soluble phosphorus.

3. Practices that involve residue management (e.g., no-till, minimum-till) have unpredictable results because vegetative residues can be a source of soluble nutrients while reducing erosion and particulate outputs.

4. Practices that do not involve residue management (e.g., terracing, contour farming) are moderately effective at reducing soluble phosphorus in runoff.

In situations where application rate, timing, and method are well-matched with crop requirements and appropriate field management, very small quantities of nutrients will be available to pollute receiving watersheds. All of the considerations listed above apply not only to farmers, but also to homeowners near the lakes and their tributaries.

Another important component of preventing nutrients from reaching surface water in agricultural and residential areas includes proper animal waste management. Factors that influence nutrient content of animal waste and its eventual availability to plants are: (1) method of waste collection; (2) length of time and the location where the waste is stored; (3) amount of feed, bedding, and/or water added to the waste; (4) timing and method of field application or ultimate disposal; (5) soil characteristics; and (6) climatic conditions. If the wastes are used as a fertilizer, then all of the considerations regarding soil testing, liming, timing, application rate, application method, and BMP selection should be employed to determine the application scenario that results in optimal plant production and minimal nonpoint source pollution. If the wastes are disposed without use as fertilizer, precautions should be taken to prevent contamination of runoff. Such precautions include proper disposal location, adequate vegetative cover between disposal area and surface water, and sufficient measures to restrict erosion of wastes during storm events.

4.1.3 Wetland Creation and Restoration

Wetlands situated within an agricultural watershed may act as natural filters trapping and immobilizing nutrients in runoff. Retention rates as high as 91% of total phosphorus and 86% of nitrate in runoff have been reported for wetlands (Adamus, 1983). The Fish and Royer Lake watershed contains numerous small wetlands in addition to the sizable complex at Grass Lake. The land use survey estimated that approximately 486 acres (197 ha) of wetlands currently exist within the watershed. To maintain the present level of water quality in the lakes, efforts to preserve this valuable resource should be pursued. Enhancement of water quality may be achieved through the restoration or enhancement of wetlands drained for agricultural purposes or residential development.

In general, wetland restoration at the site of an existing, but damaged or destroyed wetland (e.g., agricultural, drained wetlands) will have a greater change of success in terms of creating the full range of prior functions and long-term persistence than created wetlands at previously non-wetland locations. This is because pre-existing hydrologic conditions are often more or less intact, seedstock for wetland plants are present in the soils, and fauna may re-establish themselves from adjacent areas.

The following criteria should be considered in identifying and evaluating candidate sites for wetland restoration:

- The wetland should be along a tributary to the lake, preferably situated such that a significant volume of runoff flows through the wetland prior to entering the tributary stream.

- Emergent and scrub/shrub wetlands are preferred over forested wetlands because they are easier to create or restore.

- Site should be either an established wetland, as indicated on National Wetland Inventory (NWI) maps, or, at a minimum, situated on hydric soils. The Fish and Royer Lakes watershed is covered by the Wolcottville and Mongo NWI maps, which may be obtained from the U.S. Geological Survey in Reston, Virginia.

The use of NWI maps to locate candidate sites has two limitations: 1) they are somewhat dated and may show wetlands that no longer exist; and 2) they are generally not complete and may not show wetlands that are suitable for restoration. For these reasons, site specific investigations are normally required to assess the feasibility of wetland creation or restoration in an area.

4.1.4 Suggestions for Homeowners

The same principles of reducing sediment and nutrient inputs to surface water apply to both farmers and homeowners living in the Fish and Royer watershed. Residents living near the lakes or tributaries should ensure that lawn care and gardening practices do not create conditions that favor export of pollutants to the lakes. This section briefly outlines some suggestions for minimizing residential impacts on the water bodies. The Indiana Cooperative Extension Service should be able to provide more information upon request.

The following suggestions for lawn/garden care should be considered by all residents living in the watershed:

1. Avoid using fertilizers, herbicides, and pesticides unless persistent bare patches are present in the lawn. Residential lawn-care products are a major source of ground and surface water pollutants.

2. If fertilizers are required, test the soil to determine the amount of additional nutrients and/or liming needed. Add only the amounts of fertilizer/lime that are indicated by the tests. Use well-directed application methods rather than broadcast techniques to ensure treatment of problem areas only.

3. Mow grass frequently to avoid scalping and thatch build-up. Cutting the grass too short destroys the food-making capability of the blades and increases lawn susceptibility to disease, drought, and weed infestation. Establish a schedule that ensures mowing will not cut off more than 1/3 of the grass blade at any one time.

4. Allow grass clippings to remain on the lawn unless excessive thatch build-up occurs (frequent mowing will prevent thatch). Ideally, grass should be allowed to compost on the lawn to provide nutrients without the use of commercial fertilizers. It has been estimated that leaving grass clippings on lawns will reduce the need for artificial nutrients by 20-30% the first year and by 35-40% each subsequent year (Hugo, 1990).

5. Do not bag clippings or leaves for disposal in a landfill. Nationwide, these materials constitute 15-20% of all substances placed in landfills. Grass thatch and raked leaves should be composted to provide nutrients for gardens and shrubs. Care should be exercised when establishing compost piles because they too can become a significant source of nutrients if adequate runoff protection (e.g., vegetative buffer strip) is not afforded.

Trash cans and dumpsters near the lake and tributaries should be emptied and cleaned on a routine basis. They should not be placed in areas that receive or influence runoff that reaches the lake. These containers should be covered so that rain water cannot enter. Drainage holes should not be drilled into the bottoms of such receptacles because water percolating through a trash can is high in both nutrient and bacterial content. Spillage should be avoided when emptying the receptacles and any stray materials should be retrieved and discarded properly.

The importance of domestic animal manure should be brought to the attention of homeowners in the residential areas near both lakes. Because pet droppings have been identified as a major source of nutrients and bacterial contamination in suburban areas, all homeowners should be encouraged to pick up pet wastes and dispose of them properly on a daily basis.

An excellent reference on actions that homeowners can take to control pollution is available from the Conservation Foundation and the National Audubon Society. This book, Controlling Nonpoint-Source Pollution: A Citizen's Handbook, by N. Hansen, H. Babcock, and E. Clark, can be purchased for approximately $15 by writing to:

The Conservation Foundation
1250 24th Street, NW
Washington, DC 20037

4.2 SEPTIC SYSTEM REMEDIES

Aging septic leach fields in muck and sandy soils appear to be a potentially significant source of nutrients to Fish and Royer Lakes. The problem may be summarized as being the result of septic systems that were installed in soils that have poor or unsuitable drainage and pollutant retention characteristics. It has been assumed that the replacing septic systems with connections to sanitary sewer system is economically infeasible because of the distance to the nearest existing sewage treatment plant (i.e., more than 7 miles) and the small number of households that would have to share the cost of constructing a new facility.

4.2.1 Improved Maintenance of Existing Systems

The simplest action that can be taken to reduce septic system nutrient inputs consists of improved maintenance of the existing systems. Basic maintenance normally includes having the septic tank pumped out annually. Unfortunately, it is not uncommon for homeowners to have their tanks pumped only when there is a very visible problem with the system. Prolonged intervals between pumping results in a decreased life expectancy for the system and increased nutrient loading to the drain field. Increasing the frequency of routine cleaning to every six months will help remove nutrients that would otherwise go out through the drain field and into the lake. The current cost of pumping in LaGrange County is between $50 and $60.

Every component of the septic system should be kept in optimum operating condition. Collapsed drain pipes, leaking tanks, and other signs of failure should be repaired immediately, and upgraded with new designs whenever possible. To determine whether there are any septic tanks that discharge directly to the lake, a dye testing program may be initiated in cooperation with the County health department. Be alert to the warning signs of failing systems which include sewage surfacing over the drainfield; lush, green growth over the drainfield; slowly draining toilets or drains; and sewage odors. Homeowners can also maintain their septic systems by practicing the following:

- Divert roof drains and surface water from driveways and hillsides away from the septic system (including the septic tank and the drain field).

- Take leftover hazardous household chemicals to approved hazardous waste collection centers for disposal. Do not pour poisons (i.e., gasoline, oil, paint thinner, pesticides, antifreeze) into drains because they kill the beneficial bacteria that treat wastewater in septic systems.

- The area over the drainfield should be left undisturbed with only a mowed grass cover.

- Do not use commercial septic tank additives as these products usually do not help and some may harm the system in the long run.

- Do not use the septic tank as a trash can by dumping nondegradables (i.e., grease, disposable diapers, plastics) down toilets or drains.

4.2.2 Replacement Systems

Given that most of the septic systems surrounding Fish and Royer Lakes are between 20 and 30 years old, and the fact that the LaGrange County Board of Health estimates a half-life of as little as 5 years for systems installed in poorly-drained soils, the replacement of failed systems in the near future should be considered inevitable. In all such cases, the first consideration should be given to replacement with improved designs that are better suited to local conditions.

As has been stated, the resident soils are poorly suited to use as septic drain fields. The use of conventional or modified septic systems with the most advanced design features may be appropriate on certain properties around lakes where conditions are such that the systems can be located to minimize the potential for contamination of the lake. An example of one such alternative design is the mound system, where backfilled material is used to elevate the bottom of the drainfield above the normal grade. Although the evaluation of specific site conditions and design alternatives is beyond the scope of this investigation, soil conditions and proximity to the lake and water table should be primary concerns in evaluating candidate sites. Perkins (1989), or a similar text, will provide a good general reference for basic design considerations. Price estimates for replacing a single-home septic tank (i.e., 1,000 gallon tank) range from \$2,100 to \$3,000. Final costs depend on location, design, size of tank, and installation charges.

Another potentially feasible solution may exist in the construction of small-scale waste treatment facilities. Available treatment technologies include extended aeration "package" treatment plants and recirculating sand or stone filter systems. The estimated costs of constructing and operating a small extended aeration facility vary greatly with the volume of discharge. However, some of the design considerations and the magnitude of costs involved may be illustrated in a simple example. The volume of wastewater generated by homes bordering Fish and Royer Lakes was estimated for each of the housing developments using the procedure outlined in Section 3.3.6 (i.e., number of dwellings x persons/dwelling x wastewater/person/day). Table 4-2 gives the resulting approximate volumes by development for each lake. Developments in close proximity to each other might be connected served by a single package plant to reduce costs. The Oakwood Hill Trailer Park, for example, drains partially into Fish Lake and partially into Royer Lake. A single facility for this park would handle 5,000-6,000 gallons per day (gpd) and eliminate the need for two separate facilities.

An engineering economy analysis prepared by the Tennessee Division of Water Pollution Control for costs associated with facilities handling from 3,000 to 30,000 gallons per day is summarized in Table 4-3. These data were obtained from the National Small Flows Clearinghouse (See Section 4.3). These costs assume an expected lifetime of 20 years and an interest rate of 7%. Operator salaries were taken from

Table 4-2. Estimates of daily wastewater generated by developments along Fish and Royer Lakes.

Fish Lake

Development	Wastewater Flow (gpd)
Oakwood Hill	3397.0
Oakdale	1981.5
North Shore	4104.6
East Shore	1698.5
Bob's Addition	707.7

Royer Lake

Development	Wastewater Flow (gpd)
Oakwood Hill	2123.1
Reed's	5095.4
Royer Lake Resort	4387.7
Holiday	3396.9
Duessler's	3255.4

actual salaries in the Knoxville, Tennessee area. All costs are expressed in 1987 dollars. The greatest savings in cost per design gallon are achieved by increasing gallons per day from 3,000 to 10,000. Ideally, as many homes as practically possible should be connected to a single package treatment facility, taking into consideration local gradients and piping distances.

Table 4-3. Capital and O&M costs for package treatment facilities (1987 dollars).

	Design Flow (gpd)			
Component Cost	3,000	10,000	20,000	30,000
Capitol Cost Installed	$34,000	$64,000	$82,000	$98,000
Total Annual Cost (O&M + Capital)	$11,839	$18,532	$25,250	$30,950
Total Cost as $/design gallon for 20 years	$41.80	$19.60	$13.40	$11.30

Package treatment plants are relatively very expensive for each gallon treated for flows below 10,000 to 20,000 gallons per day. Recirculating sand filter systems offer a potentially less expensive alternative. For comparison, Table 4-4 presents a summary of costs for various size sand filter systems. It can be seen from this table that the annual cost per design gallon treated is significantly lower than that for comparably sized extended aeration systems. It might be noted that the costs shown in Table 4-4 represent early designs. The National Small Flows Clearinghouse estimates that costs of the newest systems may be 30 percent lower.

Table 4-4. Capital and O&M costs for recirculating sand filter treatment facilities (1987 dollars).

	Design Flow (gpd)		
Component Cost	5,000	10,000	15,000
Capitol Cost Installed	$33,000	$53,700	$77,800
Total Annual Cost (O&M + Capital)	$5,123	$7,769	$11,349
Total Cost as $/design gallon for 20 years	$10.80	$8.20	$8.00

The technical and economic feasibility of constructing one or more small-scale waste treatment facilities is beyond the scope of this investigation, and would require a specific investigation and comparison of the engineering and economic aspects of various waste treatment alternatives. It should also be recognized that treatment systems that do not employ drain fields discharge treated effluent into the environment, usually into receiving waters (e.g., streams). The environmental impacts of these discharges are often significant and unacceptable, and may prevent certain technologies from being feasible at some sites.

4.3 FUNDING SOURCES

The costs associated with the technologies discussed in preceding sections are frequently beyond the financial resources of small communities such as exist within the Fish and Royer Lakes watershed. This is especially true of sewer system retrofits. There are some available mechanisms for small communities to obtain funding for these types of activities.

The most comprehensive source of information on waste treatment technology for small communities, including funding arrangements, is the National Small Flows Clearinghouse, funded by the U.S.

Environmental Protection Agency (US EPA). A wide range of publications are available at little or no cost. Information may be obtained from:

The National Small Flows Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown, WV 26506-6064

Unfortunately, the U.S. EPA recently ended its program providing grants to small communities for the construction of conventional sewerage treatment plants.

Funding for agricultural BMPs is available through cost-share provisions of the "T by 2000" cropland erosion control program sponsored by the Indiana Department of Natural Resources. The Indiana Lake Enhancement Program's Upland Watershed Treatment Program has been specifically established to promote sediment and nutrient control through the installation of a wide variety of BMPs. Funding is provided at different levels of cost-sharing depending on the proximity of the land to surface waters; the highest percentage sharing is offered to fund projects that will have the greatest impact on the receiving waters. Various Federal agencies (i.e., SCS and ASCS) also offer cost-share programs.

A highly successful program to restore drained agricultural wetlands is currently being implemented by the USFWS in conjunction with the USDA Conservation Reserve Program (CRP). Under this program, drained wetlands are restored at no cost to farm owners. If the wetland is enrolled in the CRP, the farm owner may even receive annual rental payments from the USDA. More information on this program may be obtained through James Ruwaldt, USFWS - Bloomington Field Office (telephone: 812-334-4261).

The U.S. Environmental Protection Agency funds a limited number of lake restoration projects through the Clean Lakes Program. The application process is similar to that required for LEP grants. Details can be obtained through the U.S. EPA Region VI office in Chicago, IL (telephone: 312-353-2000).

SECTION 5. SUMMARY AND RECOMMENDATIONS

This section presents a summary of the findings of this study. Principal recommendations are presented for the mitigation of the sediment and nutrient problems identified during the study.

5.1 SUMMARY

Based on the results of the watershed analyses, lake and tributary sampling, and visual observations, Fish and Royer Lakes appear to be adversely impacted in the following ways:

- Primary sources of nutrients include: (1) septic systems situated in the poorly drained soils along the lake shores; (2) agricultural runoff entering the lakes primarily through their tributaries; and (3) residential runoff from the lawns and gardens located along the lakes.

- The main body of Fish Lake appears to be relatively healthy. The lake is, however, experiencing some problems with increased nutrient loading from farmsteads.

- Royer Lake is influenced largely by runoff from the predominantly agricultural watershed. Large amounts of sediments and nutrients enter Royer via the tributary that empties into the eastern side of the lake. The tributary entering Royer on its southwestern end also contributes significant amounts of sediments and nutrients. In addition, the water body probably receives some nutrients from septic systems near the lake. Trophic conditions in Royer may be expected to deteriorate in the future under the current runoff loading conditions.

- Nutrient loading from the atmosphere may be significant in both lakes, particularly with regard to nitrogen. Management techniques, however, are not readily available for reducing such input.

5.2 RECOMMENDATIONS

Approaches to restoring and protecting the quality of Fish and Royer Lakes should include both upland and in-lake measures. The preservation of existing wetlands, installation of agricultural best management practices and septic tank maintenance should be given the highest priority. The recommended actions may be summarized as follows:

- The Fish & Royer Lake Association should attempt to identify significant wetlands (i.e. those adjacent to tributaries) within the watersheds of the two lakes. Preservation of these areas is critical to maintaining the current level of water quality. Since most of the wetlands in the Fish & Royer Lake watershed are within private ownership, property owners should be educated on the values of wetlands. Restoration of drained wetlands, especially on agricultural tracts, should be encouraged. Further information on wetland values, preservation strategies, and restoration may be obtained through the IDNR - Division of Water (317) 232-4160, the IDEM - Office of Water Management (317) 243-5035, the USFWS, Bloomington Field Office (812) 334-4261, EPA Region V, Chicago (312) 886-6115, and the U.S. Army Corps of Engineers, Detroit District (313) 226-2432.

- The Fish & Royer Lake Association, and other residents in the watershed should become familiar with agricultural best management practices (BMPs) for controlling sediment and nutrient export to surface water bodies. The Fish & Royer Lake Association should work with the local SCS District Conservationist's office, the LaGrange County Soil and Water Conservation District, and the IDNR to encourage area farmers to install appropriate BMPs in locations deemed critical for preserving the quality of the lake resource. SCS is the agency that is responsible for coordinating the placement of BMPs with farmers and will provide free advice to landowners on appropriate strategies and designs. The IDNR can provide monetary assistance by way of the "T by 2000" cropland erosion control cost share program.

- Homeowners along Fish and Royer Lakes should review alternatives to the current septic system arrangement, including improved on-site treatment systems and the construction of small-scale comprehensive waste water treatment facilities. Soil conditions and proximity to the lakes and water tables should be the most critical factors in selecting candidate sites for leach fields. An engineering feasibility study will be required to fully evaluate the available technological options.

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